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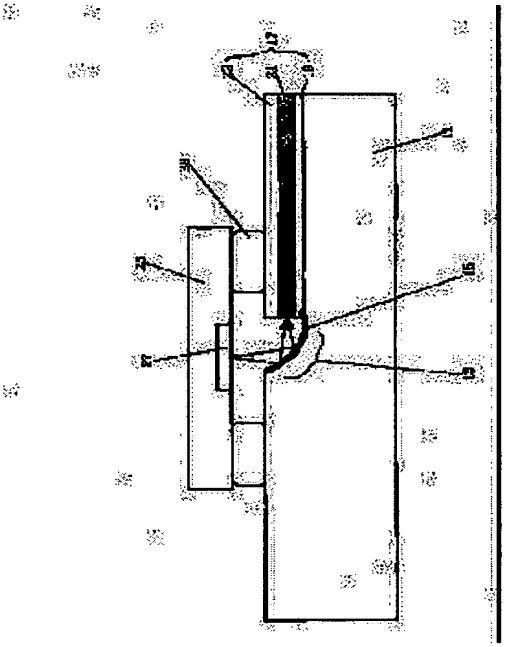
(54) PHOTO-COUPLER, ITS MANUFACTURING METHOD, AND OPTICAL TRANSMITTER-RECEIVER AND OPTICAL INTERCONNECTION DEVICE USING THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a manufacturing method by which a photo-coupler capable of optically coupling optical devices to each other with efficiency, and has a simple construction, and is easily decreased in size and arrayed, and by which an ellipsoidal surface constructed of a part of almost an ellipsoidal sphere can easily manufactured with good productivity.
SOLUTION: This photo-coupler optically couplers a 1st optical device 27 and a 2nd optical device 17 to each other by ellipsoidal surface mirrors 13, 15 constructed of a part of almost an ellipsoidal sphere.



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CLAIMS

[Claim(s)]
[Claim 1] The optical coupling machine characterized by having combined the 1st optical device and the 2nd optical device optically by the ellipse ball curved-surface mirror which consisted of some ellipse balls mostly.
[Claim 2] The 1st optical device and the 2nd optical device are an optical coupling machine according to claim 1 which is either of the optical waveguides, such as light-receiving devices, such as a photodiode which consisted of luminescence devices, such as a surface emission-type laser which consisted of semiconducting crystals, and a light emitting diode, and a semiconducting crystal, respectively, and an optical fiber.
[Claim 3] The 1st optical device and the 2nd optical device turn to the direction which accomplishes an almost right-angled include angle, are located, and are an optical coupling machine of this include angle according to claim 1 or 2 with which said ellipse ball curved-surface mirror is arranged mostly in the center position.
[Claim 4] The 1st optical device is an optical coupling machine according to claim 1, 2, or 3 which is the the optical waveguide which guides light in the direction parallel to a substrate.
[Claim 5] Said optical waveguide is an optical coupling machine according to claim 4 which consists of the resin or glass formed on said substrate.
[Claim 6] Optical waveguide is an optical coupling machine according to claim 4 which consists of an optical fiber arranged on said substrate.
[Claim 7] The 2nd optical device is an optical coupling machine according to claim 4, 5, or 6 which is the two-dimensional optical device which emits for it light or receives the light of a in general perpendicular direction to said substrate.
[Claim 8] Said ellipse ball curved-surface mirror is an optical coupling machine given in claim 4 thru/or any of 7 they are. [which is the concave surface mirrors which were located near the end face of said optical waveguide, and were formed in said substrate by etching or imprint]
[Claim 9] The optical coupling machine according to claim 1, 2, or 3 with which the ellipse ball curved-surface mirror which consists of ellipse ball-like heights is prepared on the part of this optical device of the substrate with which the two-dimensional optical device which emits light or receives light is formed.
[Claim 10] An optical coupling machine given in claim 1 thru/or any of 9 they are. [by which the optical device of **** 1 is arranged near one focus between two foci of the ellipse ball of said ellipse ball curved-surface mirror, and the 2nd optical device is arranged near the focus of another side]
[Claim 11] The optical coupling machine according to claim 10 with which the two-dimensional optical device which emits light or receives light near one focus between two foci of the ellipse ball of said ellipse ball curved-surface mirror is arranged, and the end face of optical waveguide is arranged near the focus of another side.
[Claim 12] An optical coupling machine given in claim 1 thru/or any of 11 they are. [by which the high reflective film is formed in the curved surface of said ellipse ball curved-surface mirror]

[Claim 13] The production approach of the process at which the ellipse ball curved surface which consisted of some ellipse balls mostly forms the slant face which has a predetermined include angle on the (a) substrate, the process which forms the mask which has opening of the shape of the shape of a rectangle, and an ellipse on (b) this slant face, the process which etch a substrate isotropic through (c) this opening, and the ellipse ball curved surface which are characterized by to be formed that it is alike.
[Claim 14] The production approach of the optical coupling machine characterized by etching the substrate which forms said ellipse ball curved-surface mirror by the production approach according to claim 13 in the production approach of an optical coupling machine given in any [claim 1 thru/or] of 12 12 they are.
[Claim 15] The process for which the ellipse ball curved surface which consisted of some ellipse balls mostly prepares the substrate for plating which has (a) conductivity part at least in a part, (b) by the process which forms the mask which has opening on the conductive part of this substrate for plating, and and electroplating which used the conductive part of (c) this substrate for plating as cathode The production approach of the ellipse ball curved surface characterized by the process which imprints the configuration of a deposit to other substrates, and forming "Be alike" by using as metal mold the substrate for plating which has the process which forms a deposit on opening and a mask through said opening, and (d) this deposit.
[Claim 16] The production approach according to claim 15 which the slant face which has a predetermined include angle beforehand is formed in said substrate for plating, and forms the mask which has opening on this slant face.
[Claim 17] Said opening is the production approach according to claim 15 or 16 which has the shape of the shape of a rectangle, and an ellipse, and forms an ellipse ball-like deposit in the condition of having made plating liquid standing it still, in the process of the above (c).
[Claim 18] Said opening is the production approach according to claim 15 or 16 which is a circle configuration and forms an ellipse ball-like deposit in the process of the above (c) by making plating liquid flow in the predetermined rate of flow to an one direction on opening.
[Claim 19] The production approach of the optical coupling machine characterized by imprinting the configuration of said deposit formed in claim 15 thru/or any of 18 by the production approach of a publication at the substrate which forms said ellipse ball curved-surface mirror in the production approach of an optical coupling machine given in any [claim 1 thru/or] of 12 they are.
[Claim 20] The production approach of the optical coupling machine characterized by forming ellipse ball-like heights on the substrate with which the optical device is formed by using as metal mold the substrate which has the crevice of the shape of an ellipse ball formed by the production approach given in any [claims 13 and 15 thru/or] of 18 they are in the production approach of an optical coupling machine according to claim 9.
[Claim 21] The optical transmitter-receiver which the optical coupling machine given in any [claim 1 thru/or] of 12 they are is formed in the both ends of optical waveguide, and is characterized by combining optically the light emitting device of a lot, a photo detector, and optical waveguide.
[Claim 22] Optical interconnection equipment characterized by performing optical wiring in a semi-conductor circuit chip using an optical transmitter-receiver according to claim 21.
[Claim 23] Optical interconnection equipment characterized by performing optical wiring of chip modules with which two or more mounting of the semi-conductor circuit chip was carried out using an optical transmitter-receiver according to claim 21.
[Claim 24] Optical interconnection equipment characterized by performing optical wiring in the board on which the semi-conductor circuit chip and the chip module were mounted using an optical transmitter-receiver according to claim 21.
[Claim 25] Optical interconnection equipment characterized by performing optical wiring of boards with which the semi-conductor circuit chip and the chip module were mounted using an optical transmitter-receiver according to claim 21.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to an optical transmitter-receiver, optical interconnection equipment, etc. using two-dimensional optical devices, such as a light emitting device and a photo detector, the optical coupling machine suitable for optical association of optical waveguide, optical association of optical waveguides, etc., and this.
[0002]
[Description of the Prior Art] In order to realize mass optical communication and a mass optical interconnection, two or more laser components are arranged in the shape of an array, and research which transmits optical information to juxtaposition is advanced. It is suitable for array-ization and the surface emission-type laser (VerticaCavity Surface Emitting Laser:VCSEL) attracts attention as a luminescence device of a low threshold. Moreover, light emitting diode is also widely used from the point of low cost. In order to apply such a two-dimensional optical device to the optical interconnection which connects between boards or between chips with light, it is necessary to carry out optical coupling of the waveguide and the two-dimensional optical device which transmit light, and the optical coupling structure where joint effectiveness is more high is demanded.
[0003] As a means to combine the optical device (for you to be waveguides, such as a light emitting device, a photo detector, or an optical fiber) which performs vertical luminescence/light-receiving to a certain substrate, and the optical waveguide which guides light in the direction parallel to this substrate, the structure which forms 45-degree mirror in ** substrate, and structure [of preparing a diffraction grating which combines ** horizontal direction and a perpendicular direction in a substrate] ** are known about such optical coupling structure.
[0004]
[Problem(s) to be Solved by the Invention] However, there are the following troubles in such an optical coupling means.
** Since a case, for example, the light from a light emitting device, is emission light, when it combines with optical waveguide through 45-degree mirror as it is, it has the problem that joint effectiveness falls. Therefore, although it is necessary to insert the lens for condensing between a light emitting device and 45-degree mirror, structure will become complicated in that case. moreover, in order to raise joint effectiveness, the type which the mirror section was incurvated and was made into cylindrical structure is also proposed -- **** (JP,5-264870,A) -- although there is a condensing operation in the direction perpendicular to a substrate also in this case, since there is no condensing operation horizontally, the decline in joint effectiveness cannot be denied.
[0005] Moreover, since a limitation is in the diffraction efficiency of the diffraction grating which changes a vertical light into a horizontal light in **, it is difficult to acquire high joint effectiveness. Moreover, it is necessary to enlarge area at improvement in effectiveness of a diffraction grating, and a limitation is in a miniaturization with this structure. In addition, since the diffraction grating which changes a vertical emission light into a horizontal focusing light has the complicated pattern, by the

interference exposing method, production is difficult and special approaches, such as an electron beam lithography, are needed for the production.
[0006] This invention is accomplished in view of the trouble of the above-mentioned conventional technique. The purpose (1) Can carry out the optical coupling of between the optical device which performs vertical luminescence or vertical light-receiving, the optical waveguides which perform a horizontal guided wave efficiently, and a configuration is simple. A miniaturization and array-ization effectively (2) optical-coupling machine which offers an easy optical coupling machine An usable optical device, (4) which offers the production approach which can produce easily (3) optical-coupling machine or the ellipse ball curved surface which consisted of some ellipse balls mostly which offers optical waveguide with sufficient productivity -- the optical transmitter-receiver using such an optical coupling machine in which a parallel transmission is possible, and optical interconnection equipment are offered -- it is especially.
[0007]
[Means for Solving the Problem and its Function] The optical coupling machine of this invention for attaining the above-mentioned purpose is characterized by having combined the 1st optical device and the 2nd optical device optically by the ellipse ball curved-surface mirror which consisted of some ellipse balls mostly. Since a horizontal direction and a perpendicular direction have a condensing operation since it is the ellipse spherical surface mostly, the optical coupling of between optical devices can be carried out efficiently and other optics, such as a lens, are not needed, a configuration is simple, and it is suitable also for a miniaturization and array-ization.
[0008] Based on the above-mentioned basic configuration, the gestalt like a less or equal is possible. The The 1st optical device and the 2nd optical device may be either of the optical waveguides, such as light-receiving devices, such as photodiodes (pin photograph DAIDO etc.) which consisted of luminescence devices, such as a surface emission-type laser which consisted of semiconducting crystals, and a light emitting diode, and a semiconducting crystal, respectively, and an optical fiber. The optical coupling of between these optical devices can be carried out good by the ellipse ball curved-surface mirror by this invention.
[0009] The 1st optical device and the 2nd optical device turn to the direction which accomplishes an almost right-angled include angle, it is located, and said ellipse ball curved-surface mirror may be arranged at the neighborhood of a point which each optical axis intersects. By leaning suitably the major axis of an ellipse ball curved-surface mirror, and installing in a position, the optical coupling of between the optical devices arranged at such an angular relation-ship can be carried out good. Moreover, one optical devices may be optical waveguides (the optical waveguide which consists of the resin or glass formed on the substrate, optical fiber arranged on a substrate) which guide light in the direction parallel to a substrate. At this time, the optical device of another side may be a two-dimensional optical device which emits for it light or receives the light of a in general perpendicular direction to said substrate. Furthermore, it may be the concave surface mirror which the ellipse ball curved-surface mirror was located near the end face of said optical waveguide, and was formed in said substrate by etching or imprint in this case.
[0010] Moreover, the gestalt with which the ellipse ball curved-surface mirror which consists of ellipse ball-like heights is prepared on the part of this optical device of the substrate with which the two-dimensional optical device which emits light or receives light is formed can also be taken.
[0011] In order to attain more efficient optical coupling, it is good to arrange the optical device of **** 1 near one focus between two foci of the ellipse ball of said ellipse ball curved-surface mirror, and to arrange the 2nd optical device near the focus of another side. In this case, the two-dimensional optical device which emits light or receives light near one focus between two foci of the ellipse ball of said ellipse ball curved-surface mirror is arranged, and the end face of optical waveguide may be arranged near the focus of another side.
[0012] In order to attain optical coupling efficient same more, it is good for the curved surface of said ellipse ball curved-surface mirror to form the high reflective film.
[0013] Furthermore, it sets to the production approach of the ellipse ball curved surface of this invention

for attaining the above-mentioned purpose. The process at which the ellipse ball curved surface which consisted of some ellipse balls mostly forms the slant face which has a predetermined include angle on the (a) substrate, (b) It is characterized by the process which forms the mask which has opening of the shape of the shape of a rectangle, and an ellipse on this slant face, the process which etches a substrate isotropic through (c) this opening, and forming "Be alike."

[0014] The above-mentioned optical coupling machine is easily producible by etching the substrate which forms said ellipse ball curved-surface mirror by this production approach.

[0015] Moreover, it sets to the production approach of the ellipse ball curved surface of this invention for attaining the above-mentioned purpose. The process for which the ellipse ball curved surface which consisted of some ellipse balls mostly prepares the substrate for plating which has (a) conductivity part at least in a part, (b) by the process which forms the mask which has opening on the conductive part of this substrate for plating, and electroplating which used the conductive part of (c) this substrate for plating as cathode It is characterized by the process which imprints the configuration of a deposit to other substrates, and forming "Be alike" by using as metal mold the substrate for plating which has the process which forms a deposit on opening and a mask through said opening, and (d) this deposit.

[0016] By the production approach of this ellipse ball curved surface, if the slant face which has a predetermined include angle beforehand in said substrate for plating is formed and the mask which has opening is formed on this slant face, the ellipse ball curved surface which inclined suitably can be formed.

[0017] Under the present circumstances, said opening has the shape of the shape of a rectangle, and an ellipse, in the process of the above (c), said opening is a circle configuration, and in the process of the above (c), an ellipse ball-like deposit can be formed in the condition of having made plating liquid standing it still, or it can form [it can make plating liquid able to flow in the predetermined rate of flow to an one direction on opening, and] an ellipse ball-like deposit.

[0018] The above-mentioned optical coupling machine is easily producible by imprinting the configuration of said deposit formed in the substrate which forms said ellipse ball curved-surface mirror by these production approaches.

[0019] Production of the coupler of a gestalt by which the ellipse ball curved-surface mirror which consists of ellipse ball-like heights is prepared on the part of this optical device of the substrate with which the above-mentioned two-dimensional optical device is formed can be performed by forming ellipse ball-like heights on the substrate with which the optical device is formed by using as metal mold the substrate which has the crevice of the shape of an ellipse ball formed by the above-mentioned production approach.

[0020] Furthermore, the above-mentioned optical coupling machine is formed in the both ends of optical waveguide, and the optical transmitter-receiver of this invention for attaining the above-mentioned purpose is characterized by combining optically the light emitting device of a lot, a photo detector, and optical waveguide.

[0021] Furthermore, the optical interconnection equipment of this invention for attaining the above-mentioned purpose is characterized by to perform optical wiring of boards with which optical wiring or semi-conductor circuit chip, and chip module in the board on which optical wiring in a semi-conductor circuit chip, optical wiring of chip modules with which two or more mounting of the semi-conductor circuit chip was carried out, the semi-conductor circuit chip, and the chip module were mounted were mounted using the above-mentioned optical transmitter-receiver.

[0022] The operation principle of this invention is explained. Two foci exist in an ellipse ball, and when the vector to the direction of the arbitration emitted from the focus of one of these reflects on the curved surface of an ellipse ball, becoming the vector which surely passes along the focus of another side is known. That is, if a two-dimensional optical device like a surface emission-type laser is arranged and the end face of optical waveguide is arranged near the focus of another side near one focus between two foci of an ellipse ball, the emission light emitted from the two-dimensional optical device will be changed into the light which reflects on the curved surface of an ellipse ball and condenses toward optical waveguide. In this way, light is efficiently combinable. Moreover, compared with the case where 45-

degree mirror and a condenser lens are used, a configuration is simple and the alignment of each element is also easy a configuration.

[0023] As mentioned above, in order to form an ellipse ball-like curved surface, there are an approach of forming an ellipse ball-like crevice on a substrate using isotropic etching, such as wet etching, the approach of forming ellipse ball-like heights on a substrate by the electroplating method, etc., but since these approaches can form much ellipse ball structures on a substrate at coincidence, array-izing is easy for them. Moreover, the irregularity of this structure may be reversed to another substrate as metal mold, and it may be made to imprint the structure formed by these approaches. When using metal mold, since reuse of metal mold is possible, productivity improves.

[0024] Moreover, when two or more optical coupling machines of this invention are formed on a substrate, an optical coupling machine is formed in the both ends of optical waveguide, and if a light emitting device and a photo detector are arranged so that optical coupling may be further carried out to optical waveguide, the optical transmitter-receiver of a pair can be constituted. Furthermore, it is also possible to apply to the optical interconnection between the boards during the chip in a chip and in a board, and a high speed and a parallel transmission can be realized.

[0025]

[The gestalt of the example of invention] Hereafter, the gestalt of operation of this invention is explained, referring to a drawing.

[0026] (The 1st example) The 1st example of this invention is explained using drawing 1 and drawing 2 . Drawing 1 is the sectional view of the 1st example of the optical coupling machine by this invention, and drawing where drawing 2 explains the making process, in addition to a sectional view, also doubles a plan in drawing 2 , and it has indicated.

[0027] In drawing 1 , the reflective film with which 11 consists of aluminum by which Si substrate and 13 were prepared in the ellipse ball-like crevice, and 15 was prepared on that crevice 13, and 17 are optical waveguides, and this optical waveguide 17 consists of up-and-down cladding layers 19 and 23 and an up-and-down core layer 21. Furthermore, 25 is a GaAs substrate with which the two-dimensional optical device is formed, and 27 is a surface emission-type laser. Moreover, 29 is adhesives on which a substrate 11 and 25 comrades are pasted up.

[0028] The light-emitting part of a surface emission-type laser 27 and the edge (the inside of drawing 1 , left end) of a core layer 21 are arranged, respectively so that it may come to two foci of the partial ellipse ball-like crevice 13. Therefore, the light which radiated from the surface emission-type laser 27, and hit the ellipse ball-like crevice 13 will be changed into the light which reflects by the reflective film 15 and condenses toward the left end of a core 21 (see the arrow head among drawing 1). In this way, it becomes possible to combine light efficiently.

[0029] The production approach of the ellipse ball-like crevice 13 is explained using drawing 2 . The etching mask 101 is formed on the Si substrate 11 (drawing 2 (a)), and the slant face 103 which has a predetermined include angle to the datum level of a substrate 11 by anisotropic etching is formed (drawing 2 (b)). Patterning of the etching mask 101 is carried out in the direction parallel to <011> using the substrate which has a field (the above-mentioned datum plane) as this time (100) 11, for example, an Si substrate. And a slant face 103 can be made into a field (111) by using a potassium-hydroxide water solution as an etching reagent. In this case, the include angle of a substrate side (datum level) and a slant face 103 becomes 54.7 degrees.

[0030] Next, the etching mask 105 which formed the opening 107 of the rectangle which has a longitudinal direction in the direction of A-A' in the place of a slant face 103 is formed on a slant face 103 like drawing 2 (c-1) and drawing 2 (c-2).

[0031] Subsequently, it lets opening 107 pass, isotropic etching is performed using the mixed water solution of fluoric acid, a nitric acid, and an acetic acid, and the ellipse ball-like crevice 13 is formed (drawing 2 (d-1), drawing 2 (d-2)). Furthermore, the etching mask 105 is removed (drawing 2 (e-1), drawing 2 (e-2)). At this time, the major axis of the formed ellipse ball (half-ellipse ball) was 50 micrometers, and the minor axis was 25 micrometers. In this way, although the formed crevice 13 cannot be said to be a strict ellipse ball, it serves as a configuration near an ellipse ball at extent with

function sufficient as an optical coupling machine of this invention.
[0032] Furthermore, after vapor-depositing aluminum as reflective film 15 to a crevice 13, optical waveguide 17 is formed (drawing 2 (f)). Optical waveguide 17 is the configuration which covered the surroundings of the core layer 21 which consists of polyimide resin of a high refractive index by the cladding layers 19 and 23 which consist of polyimide resin of a low refractive index to this core layer 21. The cross-section configuration of a core layer 21 was made into the 4micrometerx4micrometer rectangle. Moreover, the end face of optical waveguide 17 is etched so that the edge of optical waveguide 17 may come near [one] the focus of the ellipse ball-like crevice 13. Since this setup can be compensated with the alignment of the next surface emission-type laser 27, it is good for the appearance described here near [one] the focus.
[0033] Production of this optical waveguide 17 is performed by etching of patterning after membrane formation of a cladding layer 19, and membrane formation of core materials, formation (membrane formation and lift off of the core layer 21 after the mask formation which has a pattern are sufficient) of the core layer 21 by etching, membrane formation of both the sides of a core layer 21, and the upper cladding layer 23, and the left end section of optical waveguide 17.
[0034] Thus, a surface emission-type laser 27 is pasted up like drawing 1 on the produced optical waveguide 17 and the substrate 11 containing a mirror 15. In order to make adhesion easy in advance of this adhesion, and to make the luminescence edge of a surface emission-type laser 27 easy to double with the focus of another side of the ellipse ball-like crevice 13, flattening processing of the front face of the Si substrate 11 is carried out. In this example, ultraviolet-rays hardenability resin is used as adhesives 29.
[0035] In the configuration of drawing 1 , in order to determine the helicopter loading site of a surface emission-type laser 27, it is performed as follows. The optical power meter is prepared in the other end side which is not illustrating optical waveguide 17, it moves little by little on a substrate 11 in the condition of having made the surface emission-type laser 27 emitting light, adhesives 29 are stiffened in the place where the output of a power meter became max, and the laser component 27 is fixed. Thereby, the etching error of the end face of the above-mentioned optical waveguide 17 can be compensated.
[0036] Moreover, as other approaches, beforehand, the alignment marker is prepared in both substrates 11 and 25 so that easily [positioning], and alignment of the laser component 27 may be performed by doubling both markers.
[0037] as mentioned above -- since there is a condensing operation in all the cross sections around the shaft to which two foci, not only the inside of the cross section of drawing 1 but an ellipse ball, are connected with this example -- association -- while a high effectiveness optical coupling machine is realizable, compared with the conventional example of using a surface emission-type laser, a condenser lens, and 45-degree mirror, a configuration is simple and excellent also in the miniaturization.
[0038] In this example, although the surface emission-type laser was used as a two-dimensional optical device, you may be a light-receiving device like photo diode in being a light emitting diode, for example. Furthermore, other optical waveguide edges, such as an optical fiber, may be installed in the place of the luminescence part of the device 27 of drawing 1 .
[0039] Moreover, although ultraviolet-rays hardening resin was used as adhesives, you may be heat-curing resin. As a substrate 11, a substrate may be pasted up using Si substrate with which wiring is given, electroconductive glue, a pewter, etc. performing adhesion and electrical installation of the electrode pads by the side of both substrates.
[0040] Moreover, opening 107 may be elliptical. As optical waveguide, although constituted from polyimide resin, you may be glass ingredients, such as SiO2 and SiNx. In addition, flexible waveguide like an optical fiber may be arranged so that the waveguide edge may come to one focus of an ellipse spherical crevice. At this time, a guide like a V groove may be prepared on a substrate 11 so that easily [the alignment of flexible waveguide].
[0041] Moreover, although the field is used as an Si substrate 11 (100), the include angle to the datum level of the substrate of a field which appears by anisotropic etching (111) is changeable by using the substrate of another field bearing. Moreover, as long as a smooth slant face is obtained, it is not what

was restricted to anisotropy wet etching, and a substrate may be etched by dry etching etc.
[0042] Furthermore, you may be not the thing restricted to Si substrate but a quartz substrate, other glass substrates, etc. Although aluminum was used as reflective film 15, you may be metals, such as Au, and may be dielectric multilayers, such as Si/SiO2, for example.
[0043] (The 2nd example) The another production approach of the optical coupling machine of this invention is shown using drawing 3 and drawing 4 . In this 2nd example, it is the description to form ellipse ball-like heights using an electroplating method.
[0044] First, the etching mask 201 is formed on the Si substrate 211 (drawing 3 (a)), and the slant face 203 which has a predetermined include angle to the datum level of a substrate 211 is formed by anisotropic etching (drawing 3 (b)). Patterning of the etching mask 201 is carried out in the direction parallel to <011> using [at this time, for example, the substrate which has a field as Si substrates 211 (100),]. And a slant face 203 can be made into a field (111) by using a potassium-hydroxide water solution as an etching reagent. Also in this case, the include angle of a substrate side (datum level) and a slant face 203 becomes 54.7 degrees.
[0045] Next, the electrode 204 which consists of Cr/Au used as cathode like drawing 3 (c) in the case of electroplating is formed on the whole surface. Furthermore, as shown in drawing 3 (d-1) and drawing 3 (d-2), the mask 205 for plating which formed the opening 207 of the rectangle which has a longitudinal direction in the direction of A-A' in the slant face 203 is formed on a slant face 203.
[0046] Subsequently, this substrate with an electrode is used as a work piece, and electroplating is performed by using an electrode 204 as cathode using nickel plating liquid which consists of nickel nitrate, a nickel chloride, a way acid, and a brightener by the temperature of 50 degrees C, and cathode-current-density 5 A/dm2. Since nickel grows opening 207 isotropic as a core at this time, the ellipse ball-like heights 209 can be formed (drawing 3 (e-1), drawing 3 (e-2)). The formed ellipse balls (half-ellipse ball) were the major axis of 50 micrometers, and 25 micrometers of minor axes. About the formation principle and strictness of these ellipse spherical heights 209, it is the same as the situation in the case of the ellipse spherical crevice which it is only replacing electroplating and etching stated in the 1st example.
[0047] An ellipse spherical crevice is formed by using as metal mold the substrate 211 which has these ellipse spherical heights 209. Drawing 4 explains the production approach.
[0048] First, ultraviolet-rays hardening resin 312 is dropped at metal mold, the quartz substrate used as the support substrate 311 is carried on it, ultraviolet rays are irradiated, and resin 312 is hardened (refer to drawing 4 (a).). Here, the upper and lower sides are reversed and it has drawn. If metal mold is exfoliated, the structures 311 and 312 which have the crevice 313 of the shape of an ellipse ball like drawing 4 (b) will be made.
[0049] Subsequently, aluminum is vapor-deposited as reflective film 315 to a crevice 313 (drawing 4 (c)). Furthermore, optical waveguide 317 is formed (drawing 4 (d)). Optical waveguide 317 is the configuration which covered the surroundings of the core layer 321 which consists of polyimide resin of a high refractive index by the cladding layers 319 and 323 which consist of BORIIMIDO resin of a low refractive index to this core layer 321, and made the cross section of a core layer 321 the 4micrometerx4micrometer rectangle. This production is the same as the thing of the 1st example. It performs etching the left end side of optical waveguide 317 as well as the 1st example so that the edge of optical waveguide 317 may come to one focus of the ellipse ball-like crevice 313.
[0050] Then, after performing flattening processing of the produced optical waveguide 317 and the substrate 311 containing a mirror 315 like the 1st example, two-dimensional optical devices, such as a surface emission-type laser, are pasted up.
[0051] Also in this example, an optical coupling machine with high joint effectiveness is realizable like the 1st example. Furthermore, since the metal mold which consists of the structure of drawing 3 (e-1) and drawing 3 (e-2) is reusable, its productivity of an optical coupling machine improves.
[0052] In this example, although the heights 209 of the shape of an ellipse ball which consists of nickel were produced, as long as electroplating is possible for a plating ingredient, anything, it may be good, for example, may be alloys, such as single metals, such as Au, Pt, Cr, Cu, Ag, and Zn, or Cu-Zn, Sn-Co,

nickel-Fe, and Zn-nickel. Moreover, although the quartz was used as a support substrate 311, it may not be what was restricted to this, but you may be semi-conductor substrates, such as a glass substrate, Si, GaAs, and InP. Furthermore, the configuration of the opening 207 in the case of plating may be an ellipse.

[0053] (The 3rd example) The further another production approach of the optical coupling machine of this invention is shown using drawing 5 and drawing 6 . In this 3rd example, it is the description that the 2nd example forms ellipse ball-like heights using a different electroplating method.

[0054] First, on the Si substrate 411, the electrode 404 which consists of Cr/Au used as cathode in the case of electroplating is formed on the whole surface, the mask 405 for plating which consists of a photoresist is applied to the whole surface (drawing 5 (a)), and the circular opening 407 with a diameter of 5 micrometers is formed at the mask 405 for plating (drawing 5 (b)).

[0055] Subsequently, electroplating is performed by using an electrode 404 as cathode using nickel plating liquid which consists of nickel nitrate, a nickel chloride, a way acid, and a brightener, using this substrate with an electrode as a work piece. Drawing 7 explains the approach of electroplating.

[0056] In drawing 7 , 551 is an electrode by the side of an anode plate, and 553 is plating liquid. If the rate of flow is made to form on opening 407 by rotating a stirrer 555 to an one direction and making the plating liquid 553 immersed in substrates 404, 405, and 411 cause a flow of the fixed direction at this time as shown in drawing 7 , since there is more supply of a metal ion than the downstream, a growth rate will become [the direction of the upstream] quick. In this example, rotational speed of a stirrer 555 was set to 500rpm, and has arranged the opening 407 of a substrate in the location of 1cm outside from the center of rotation. Moreover, temperature of plating liquid 553 was made into 50 degrees C, and cathode current density was made into 5 A/dm2.

[0057] Consequently, it saw in the cross section which met in the flow direction of plating liquid 553, and the ellipse ball-like heights 409 which inclined toward right-hand side (upstream) like drawing 5 (d) through the condition of drawing 5 (c) have been formed. It is thought that the summit section shifts to the upstream a little in a flow of plating liquid, and the reason such ellipse spherical heights are formed with the flowing plating liquid becomes an ellipse spherical approximation object the place in which hemispherical heights are formed with quiescence plating liquid. The ellipse ball formed at this time was 15 micrometers in height in the summit section, the substrate was seen from the top and that profile was 30 micrometers long and 40 micrometers wide. The direction of a major axis of the ellipse in this cross section leans to the substrate side, as the chain line of drawing 5 (d) shows through the core of opening 407. An ellipse spherical crevice is formed by using as metal mold the substrate which has these ellipse spherical heights 409.

[0058] Drawing 6 explains the production approach. First, ultraviolet-rays hardening resin 512 is dropped at metal mold, the quartz substrate used as the support substrate 511 is carried, ultraviolet rays are irradiated, and resin 512 is hardened (refer to drawing 6 (a).). Here, the upper and lower sides are reversed and it has drawn. If metal mold is exfoliated, the structures 511 and 512 which have the crevice 513 of the shape of an ellipse ball like drawing 6 (b) will be made.

[0059] Subsequently, the field which forms optical waveguide is etched and removed (drawing 6 (c)), and aluminum is vapor-deposited as reflective film 515 to a crevice 513 (drawing 6 (d)). Then, optical waveguide 517 is formed (drawing 6 (e)). Optical waveguide 517 is the configuration which covered the surroundings of the core layer 521 which consists of polyimide resin of a high refractive index by the the cladding layers 519 and 523 which consist of polyimide resin of a low refractive index to this core layer 521, and made the cross section of a core layer 521 the 4micrometerx4micrometer rectangle. Here, the left end side of optical waveguide 517 is etched so that the edge of optical waveguide 517 may come to one focus of the ellipse ball-like crevice 513.

[0060] Then, after performing flattening processing of the produced optical waveguide 517 and the substrate 511 containing a mirror 515 like the 1st example, two-dimensional optical devices, such as a surface emission-type laser, are pasted up.

[0061] Also in this example, an optical coupling machine with high joint effectiveness is realizable like the 1st example. Furthermore, since the metal mold which consists of the structure of drawing 5 (d) is

reusable, while its productivity improves, since the process for forming a slant face in a substrate becomes unnecessary compared with the 2nd example, production becomes easy.
[0062] Also in this example, although the heights of the shape of an ellipse ball which consists of nickel were produced, as long as electroplating is possible, anything, it may be good, for example, you may be alloys, such as single metals, such as Au, Pt, Cr, Cu, Ag, and Zn, or Cu-Zn, Sn-Co, nickel-Fe, and Zn-nickel.
[0063] By the way, in the 1st thru/or the 3rd example, although the ellipse ball-like curved surface was produced by etching or electroplating, even if it uses the other approaches, for example, the physical processing means by general laser beam machining, it may be produced.
[0064] (The 4th example) Next, another example of the optical coupling machine of this invention is shown using drawing 8 . Most structures of this 4th example are the same as the 1st example, and detailed explanation of a common part is omitted. The same number is attached to the same part as drawing 1 in drawing 8 .
[0065] In this example, it has the configuration where the core layer 621 of a high refractive index is covered round with the cladding layer 619 of a low refractive index, and the left end section of a core layer 621 is located in one focus of the ellipse ball-like crevice 13, in addition the ellipse ball-like crevice 13 is also embedded by the cladding layer 619. In this example, since the process of etching finally and making it expose becomes unnecessary compared with the method of forming the optical waveguide 17 in the 1st example so that the edge of optical waveguide 617 may come to one focus of the ellipse ball-like crevice 13 mostly, the part and a process can be simplified.
[0066] (The 5th example) The 5th example by this invention is explained using drawing 9 . The optical coupling machine consists of this examples by imprinting ellipse ball-like heights on the substrate in which the two-dimensional optical device was formed, by using as metal mold the substrate which has the crevice of the shape of an ellipse ball produced in the above-mentioned example.
[0067] In drawing 9 , 701 is a GaAs substrate and 703 is the surface emission-type laser formed in the substrate 701. The heights 713 of the shape of an ellipse ball which consists of ultraviolet-rays hardening resin are formed on a substrate 701 by using as metal mold the substrate which has the crevice of the shape of an ellipse ball produced in the above-mentioned example.
[0068] Furthermore, the reflective film 715 which consists of aluminum is formed so that the predetermined field of heights 713 may be covered, and the optical waveguide 717 which surrounded the core layer 721 of a high refractive index by the cladding layers 719 and 723 of a low refractive index is formed. In order to suppress reflection by the interface of the ellipse spherical heights 713 and a core layer 721 at this time, as for the ellipse spherical heights 713 and a core layer 721, having stuck without a clearance is desirable.
[0069] Also in this example, since the light from a surface emission-type laser 703 is changed into the light which reflects by the reflective film 715 and condenses toward the edge of the core layer 721 of optical waveguide 717, optical coupling can be performed efficiently. Of course, photo detectors, such as light emitting diode and photo diode, and the edge of other photoconductive wave means may be installed instead of a surface emission-type laser.
[0070] (The 6th example) According to this invention, since a large number (plurality) formation of the crevice (or heights) of the shape of an ellipse ball of the same configuration can be carried out on the same substrate at coincidence, it is possible to form two or more optical coupling machines on a substrate.
[0071] It considers as the example using [two or more] the optical coupling machine by this invention, and the example applied to the optical transmitter-receiver is shown. In the 6th example of drawing 10 , the photo diode with which the support substrate with which 801 consisted of Si etc., the optical coupling machine with which 803 and 805 were formed in the substrate 801, the surface emission-type laser by which optical waveguide and 809 were formed in the GaAs substrate, and 811 was formed in the substrate 809 for 807, and 813 were formed in Si substrate, and 815 was formed in the substrate 813, and 817 are adhesives. The production approach is as the 1st thru/or the 3rd example having shown.
[0072] The light from a surface emission-type laser 811 is combined with optical waveguide 807

through the optical coupling machine 803. And optical waveguide 807 is guided and light is received with photo diode 815 through the optical coupling machine 805. Since it is efficient, the joint effectiveness of the optical coupling machine by this invention is made to make optical connection of a surface emission-type laser 811 and the photo diode 815 efficiently, as explained until now.
[0073] What is necessary is not to be what was restricted to this, and for the wavelength of the light to be used to respond and just to choose the combination of optimal photogenic organ/electric eye in this example, although the example of the surface emission-type laser on a GaAs substrate and the photo diode on Si substrate was shown.
[0074] (The 7th example) It considers as the case where two or more optical coupling machines by this invention are used, and the example applied to optical interconnection equipment is shown.
[0075] In the 7th example of drawing 11 , 901 is the substrate with which two or more formation of optical waveguide 905 and the optical coupling machine 903 was carried out, 911a, 911b, 911c, and 911d are LSI chips, and the electronic circuitry, the two-dimensional luminescence device, the two-dimensional light-receiving device, etc. are unified in this. Actuation is as the old example having described. The compact optical interconnection equipment which a luminescence device, a light-receiving device, an electronic circuitry, an optical coupling machine, and optical waveguide unified is realizable with this example.
[0076] In this example, although the example of optical wiring during a chip was shown, you may apply to optical wiring in the board on which optical wiring, and the chip and chip module in a chip were mounted, and optical wiring of boards with which the chip and the chip module were mounted. In this case, what is necessary is for optical waveguide just to consist of flexible waveguides, such as an optical fiber, if needed.
[0077]
[Effect of the Invention] As explained above, according to this invention, there is the following effectiveness.
(1) The optical waveguide which performs the optical device which performs vertical luminescence or vertical light-receiving mostly, and a horizontal guided wave is efficiently combinable, and a configuration is simple and can offer an optical coupling machine with easy miniaturization and array-izing.
(2) An usable optical device and optical waveguide can be effectively offered for an optical coupling machine.
(3) The production means which can produce an optical coupling machine with sufficient productivity easily can be offered.
(4) The optical transmitter-receiver using such an optical coupling machine in which a parallel transmission is possible, optical interconnection equipment, etc. can be offered.

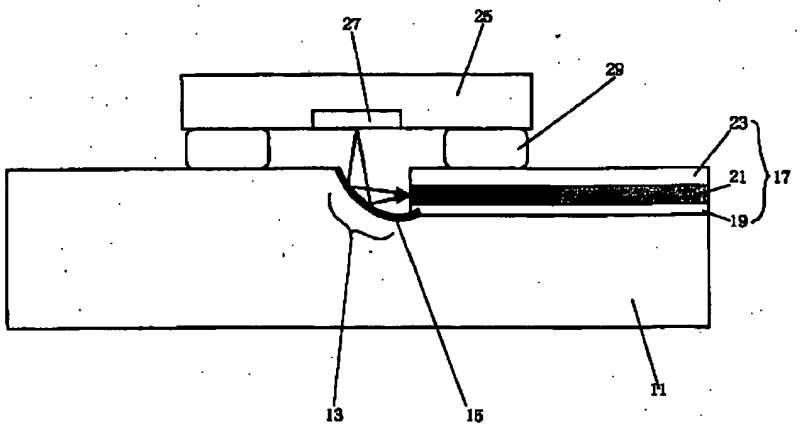
[Translation done.]

* NOTICES *

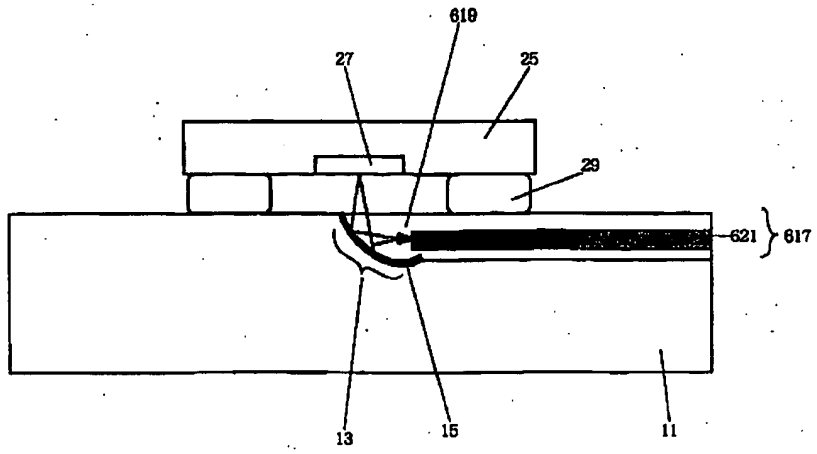
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

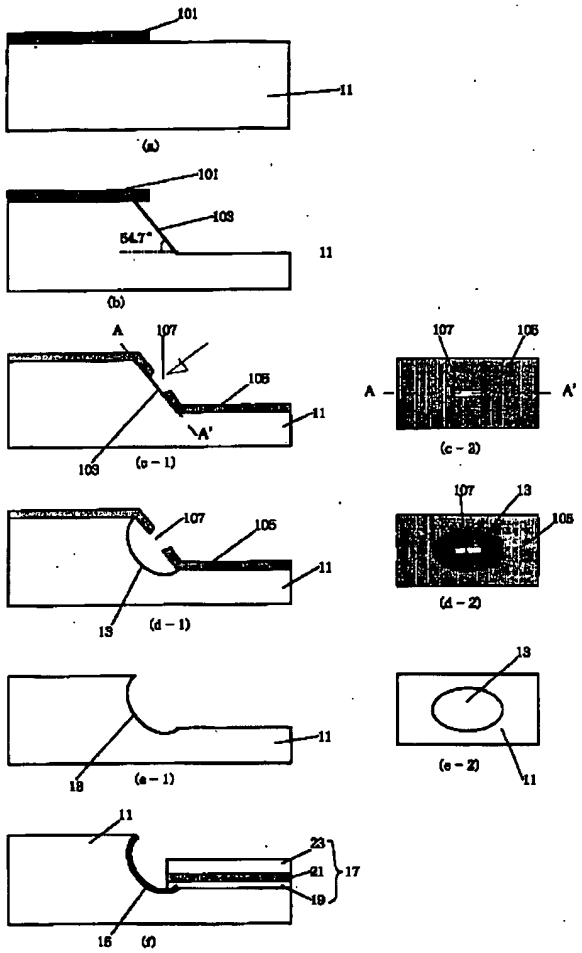
[Drawing 1]



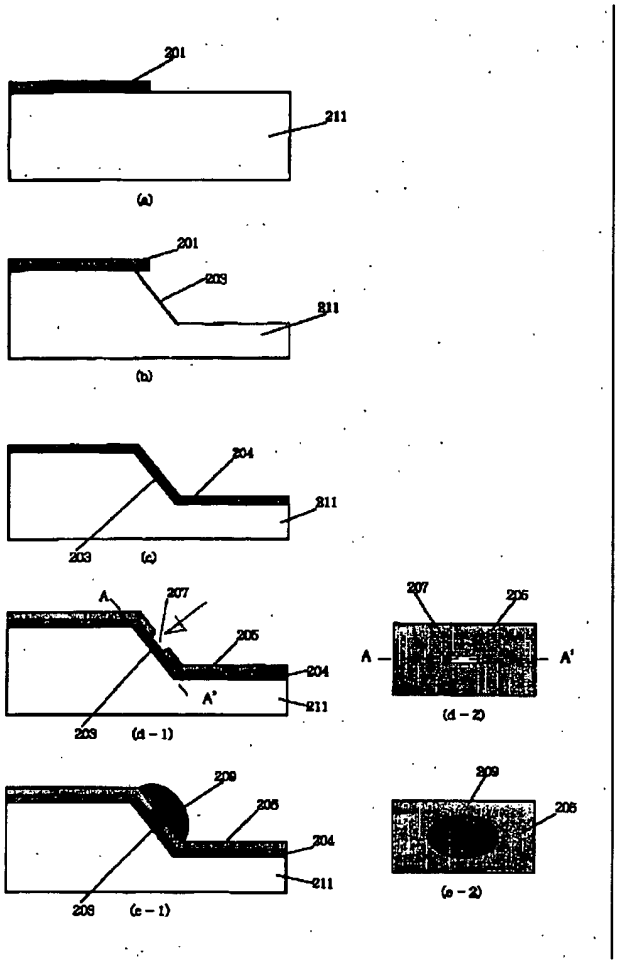
[Drawing 8]



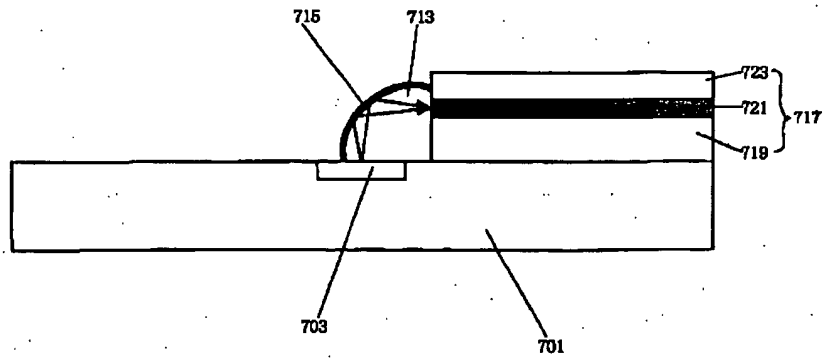
[Drawing 2]



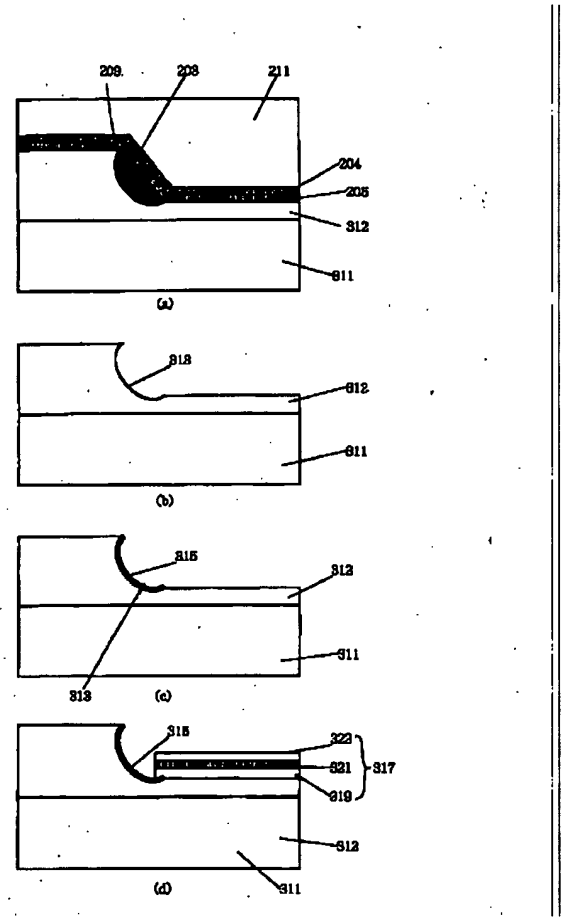
[Drawing 3]



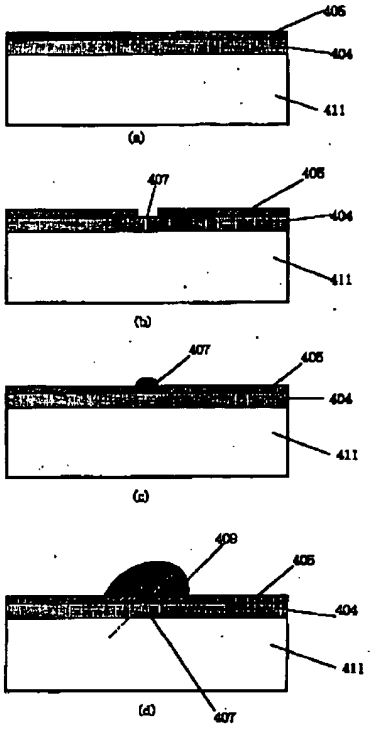
[Drawing 9]



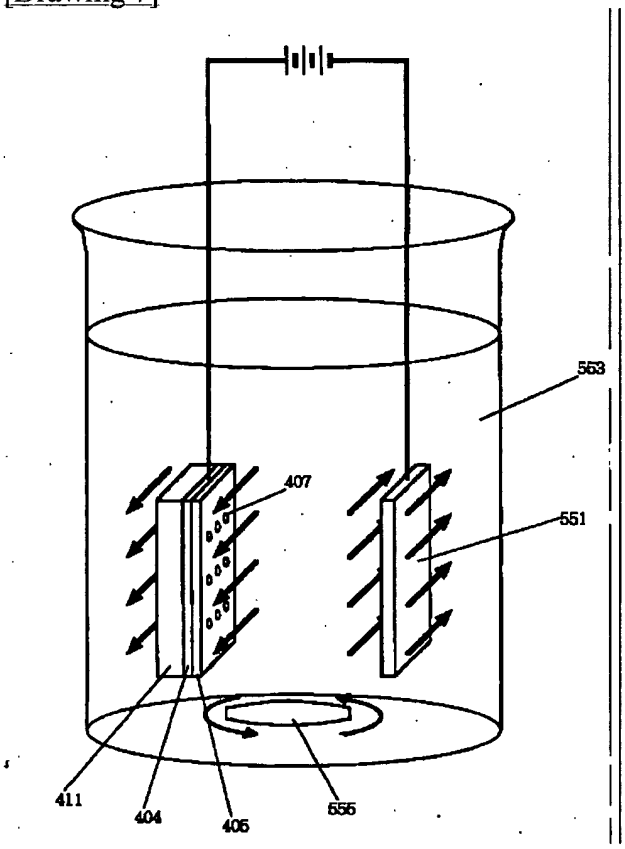
[Drawing 4]


209
208
211
204
205
312
311
(a)
313
312
311
(b)
315
312
311
313
(c)
315
323
321
317
319
312
311
(d)

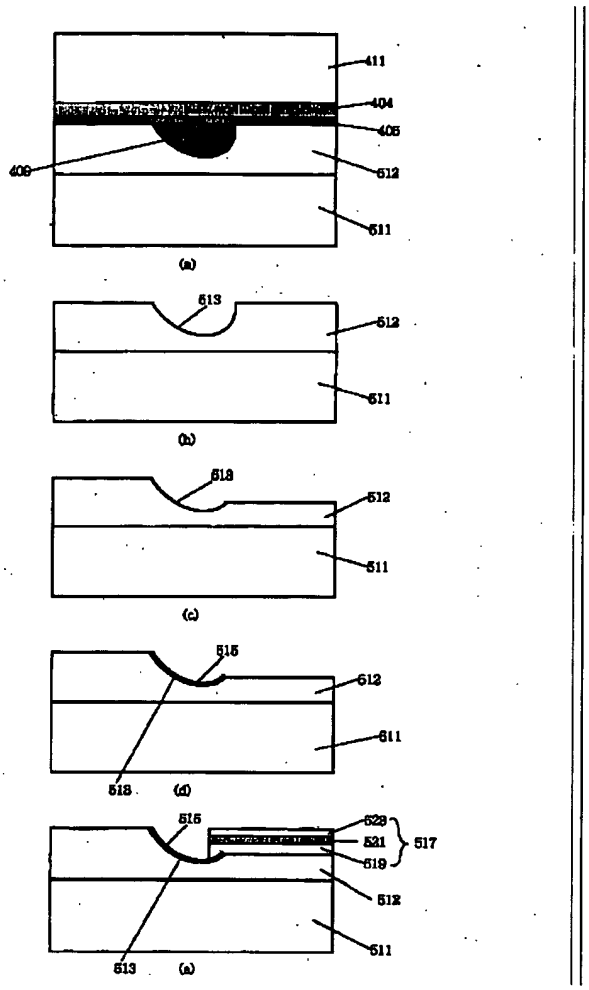
[Drawing 5]



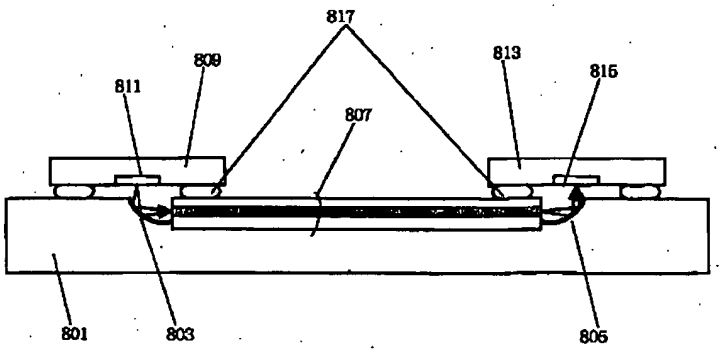
[Drawing 7]



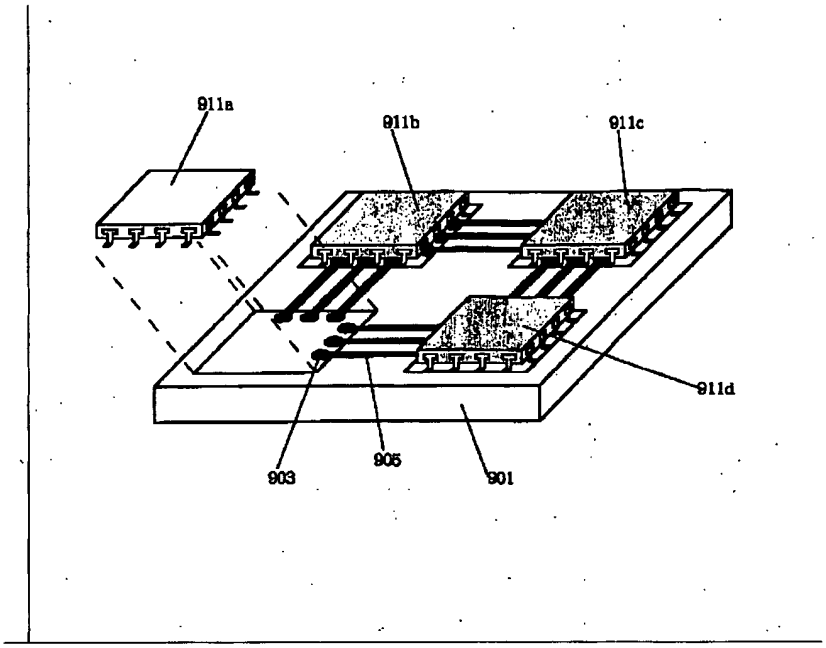
[Drawing 6]



[Drawing 10]



[Drawing 11]



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	6/122		6/24	２Ｈ０３７
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Ｈ０１Ｓ	5/022	Ｈ０１Ｌ	31/02 Ｃ	５Ｆ０８８

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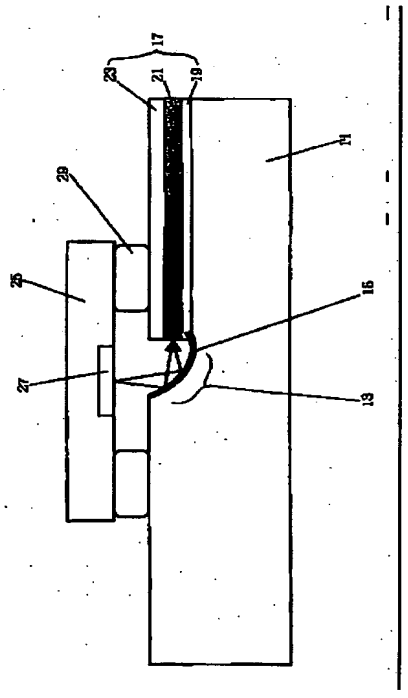
最終頁に続く

(54)【発明の名称】　光結合器、その作製方法、およびこれを用いた光送受信装置、光インターコネクション装置

(57)【要約】
【課題】光デバイス間を効率よく光結合でき、構成がシンプルで、小型化、アレイ化が容易な光結合器、ほぼ楕円球の一部から成る楕円球曲面を容易に、生産性よく作製できる作製方法である。
【解決手段】光結合器は、第１の光デバイス２７と第２の光デバイス１７とを、ほぼ楕円球の一部で構成された楕円球曲面ミラー１３、１５により光学的に結合している。



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【特許請求の範囲】

【請求項１】第１の光デバイスと第２の光デバイスとを、ほぼ楕円球の一部で構成された楕円球曲面ミラーにより光学的に結合していることを特徴とする光結合器。

【請求項２】第１の光デバイスと第２の光デバイスは、夫々、半導体結晶で構成された面発光レーザや発光ダイオードなどの発光デバイス、半導体結晶で構成されたフォトダイオードなどの受光デバイス、光ファイバなどの光導波路のいずれかである請求項１記載の光結合器。

【請求項３】第１の光デバイスと第２の光デバイスは、ほぼ直角な角度を成す方向を向いて位置しており、該角度のほぼ中心位置に前記楕円球曲面ミラーが配置されている請求項１又は２記載の光結合器。

【請求項４】第１の光デバイスは基板に平行な方向に光を導波する光導波路である請求項１、２又は３記載の光結合器。

【請求項５】前記光導波路は、前記基板上に形成された樹脂あるいはガラスからなる請求項４記載の光結合器。

【請求項６】光導波路は、前記基板上に配置された光ファイバからなる請求項４記載の光結合器。

【請求項７】第２の光デバイスは、前記基板に対し概ね垂直な方向の光を発光あるいは受光する面型光デバイスである請求項４、５又は６記載の光結合器。

【請求項８】前記楕円球曲面ミラーは、前記光導波路の端面近くに位置して、エッチング或は転写にて前記基板に形成された凹面ミラーである請求項４乃至７の何れかに記載の光結合器。

【請求項９】発光あるいは受光する面型光デバイスが形成されている基板の該光デバイスの部分上に楕円球状の凸部から成る楕円球曲面ミラーが設けられている請求項１、２又は３記載の光結合器。

【請求項１０】前記楕円球曲面ミラーの楕円球の２つの焦点のうち、一方の焦点の近傍にに第１の光デバイスが配置され、他方の焦点の近傍に第２の光デバイスが配置されている請求項１乃至９の何れかに記載の光結合器。

【請求項１１】前記楕円球曲面ミラーの楕円球の２つの焦点のうち、一方の焦点の近傍に発光あるいは受光する面型光デバイスが配置され、他方の焦点の近傍に光導波路の端面が配置されている請求項１０記載の光結合器。

【請求項１２】前記楕円球曲面ミラーの曲面には高反射膜が形成されている請求項１乃至１１の何れかに記載の光結合器。

【請求項１３】ほぼ楕円球の一部で構成された楕円球曲面が、

（ａ）基板上に所定の角度を有する斜面を形成する工程、

（ｂ）該斜面上に長方形状あるいは楕円状の開口部を有するマスクを形成する工程、

（ｃ）該開口部を通じて基板を等方的にエッチングする工程、

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によって形成されることを特徴とする楕円球曲面の作製方法。

【請求項１４】請求項１乃至１２の何れかに記載の光結合器の作製方法において、前記楕円球曲面ミラーを形成する基板を、請求項１３記載の作製方法によってエッチングすることを特徴とする光結合器の作製方法。

【請求項１５】ほぼ楕円球の一部で構成された楕円球曲面が、

（ａ）導電性部分を少なくとも一部に有するメッキ用基板を用意する工程、

（ｂ）該メッキ用基板の導電性部分上に開口部を有するマスクを形成する工程、

（ｃ）該メッキ用基板の導電性部分を陰極とした電気メッキにより、前記開口部を通じて開口部およびマスク上にメッキ層を形成する工程、

（ｄ）該メッキ層を有するメッキ用基板を金型として、他の基板にメッキ層の形状を転写する工程、

によって形成されることを特徴とする楕円球曲面の作製方法。

【請求項１６】前記メッキ用基板には予め所定の角度を有する斜面が形成されており、該斜面上に開口部を有するマスクを形成する請求項１５記載の作製方法。

【請求項１７】前記開口部は長方形状あるいは楕円状であり、前記（ｃ）の工程において、メッキ液を静止させた状態で楕円球状のメッキ層を形成する請求項１５又は１６記載の作製方法。

【請求項１８】前記開口部は円形状であり、前記（ｃ）の工程において、メッキ液を開口部上で一方向に所定の流速にて流動させることにより楕円球状のメッキ層を形成する請求項１５又は１６記載の作製方法。

【請求項１９】請求項１乃至１２の何れかに記載の光結合器の作製方法において、前記楕円球曲面ミラーを形成する基板に、請求項１５乃至１８の何れかに記載の作製方法によって形成された前記メッキ層の形状を転写することを特徴とする光結合器の作製方法。

【請求項２０】請求項９記載の光結合器の作製方法において、請求項１３及び１５乃至１８の何れかに記載の作製方法によって形成された楕円球状の凹部を有する基板を金型として、光デバイスが形成されている基板上に楕円球状の凸部を形成することを特徴とする光結合器の作製方法。

【請求項２１】請求項１乃至１２の何れかに記載の光結合器が光導波路の両端部に形成されており、一組の発光素子、受光素子、および光導波路が光学的に結合されていることを特徴とする光送受信装置。

【請求項２２】請求項２１に記載の光送受信装置を用いて、半導体回路チップ内の光配線を行なうことを特徴とする光インターコネクション装置。

【請求項２３】請求項２１に記載の光送受信装置を用いて、半導体回路チップが複数実装されたチップモジュー

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ル同士の光配線を行なうことを特徴とする光インターコネクション装置。

【請求項２４】請求項２１に記載の光送受信装置を用いて、半導体回路チップおよびチップモジュールが実装されたボード内の光配線を行なうことを特徴とする光インターコネクション装置。

【請求項２５】請求項２１に記載の光送受信装置を用いて、半導体回路チップおよびチップモジュールが実装されたボード同士の光配線を行なうことを特徴とする光インターコネクション装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、発光素子、受光素子等の面型光デバイスと光導波路の光学的な結合、光導波路同士の光学的な結合などに適した光結合器、これを用いた光送受信装置、光インターコネクション装置などに関するものである。

【０００２】

【従来の技術】大容量の光通信や光インターコネクションを実現するために、複数のレーザ素子をアレイ状に配置し、光情報を並列に伝送する研究が進められている。アレイ化に適し、低しきい値の発光デバイスとしては、面発光レーザ（ＶｅｒｔｉｃａＣａｖｉｔｙ　Ｓｕｒｆａｃｅ　Ｅｍｉｔｔｉｎｇ　Ｌａｓｅｒ：ＶＣＳＥＬ）が注目されている。また、発光ダイオードも低コストの点から広く使われている。このような面型光デバイスを、ボード間あるいはチップ間を光で接続する光インターコネクションに応用するためには、光を伝送する導波路と面型光デバイスとを光結合させる必要があり、より結合効率の高い光結合構造が要望されている。

【０００３】この様な光結合構造に関して、或る基板に対して垂直方向の発光／受光を行なう光デバイス（発光素子、受光素子、あるいは光ファイバ等の導波路であってもよい）と該基板に平行な方向に光を導波する光導波路とを結合する手段としては、

①基板に４５°ミラーを形成する構造、

②水平方向と垂直方向を結合するような回折格子を基板に設ける構造、が知られている。

【０００４】

【発明が解決しようとしている課題】しかしながら、この様な光結合手段においては次のような問題点がある。

①の場合、例えば、発光素子からの光は発散光であるため、そのまま４５°ミラーを介して光導波路に結合した場合、結合効率が低下するという問題がある。したがって、発光素子と４５°ミラーの間に集光するためのレンズを挿入する必要があるが、その場合、構造が複雑になってしまう。また、結合効率を向上させるために、ミラー部を湾曲させてシリンドリカル構造にしたタイプも提案されている（特開平５－２６４８７０号公報）が、この場合も基板に垂直な方向には集光作用があるが、水平

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方向には集光作用がないため、結合効率の低下は否めない。

【０００５】また、②の場合、垂直方向の光を水平方向の光に変換する回折格子の回折効率に限界があるため、高結合効率を得るのは困難である。また、回折格子の効率向上には面積を大きくする必要があり、この構造では小型化に限界がある。加えて、垂直方向の発散光を水平方向の集束光に変換する回折格子はパターンが複雑であるため、干渉露光法では作製は困難で、その作製には電子ビーム描画等の特殊な方法が必要となる。

【０００６】本発明は、上記従来技術の問題点に鑑み成されたものであり、その目的は、（１）垂直方向の発光あるいは受光を行なう光デバイスと水平方向の導波を行なう光導波路等の間を効率よく光結合でき、構成がシンプルで、小型化、アレイ化が容易な光結合器を提供する、（２）光結合器を効果的に使用可能な光デバイス、光導波路を提供する、（３）光結合器或はほぼ楕円球の一部で構成された楕円球曲面を容易に、生産性よく作製できる作製方法を提供する、（４）この様な光結合器を用いた並列伝送可能な光送受信装置、光インターコネクション装置を提供する、ことにある。

【０００７】

【課題を解決するための手段および作用】上記目的を達成するための本発明の光結合器は、第１の光デバイスと第２の光デバイスとを、ほぼ楕円球の一部で構成された楕円球曲面ミラーにより光学的に結合していることを特徴とする。ほぼ楕円球面であるので、水平方向及び垂直方向ともに集光作用があり、光デバイス間を効率よく光結合でき、レンズ等の他の光学部品を必要としないので構成がシンプルで、小型化、アレイ化にも適する。

【０００８】上記基本構成に基づいて、以下の如き形態が可能である。第１の光デバイスと第２の光デバイスは、夫々、半導体結晶で構成された面発光レーザや発光ダイオードなどの発光デバイス、半導体結晶で構成されたフォトダイオード（ｐｉｎフォトダイードなど）などの受光デバイス、光ファイバなどの光導波路のいずれかであり得る。これらの光デバイス間を本発明による楕円球曲面ミラーにより良好に光結合できる。

【０００９】第１の光デバイスと第２の光デバイスは、ほぼ直角な角度を成す方向を向いて位置しており、夫々の光軸が交差する点の近傍に前記楕円球曲面ミラーが配置され得る。楕円球曲面ミラーの長軸を適当に傾けて所定の位置に設置することで、この様な角度関係に配置された光デバイス間を良好に光結合できる。また、一方の光デバイスは基板に平行な方向に光を導波する光導波路（基板上に形成された樹脂あるいはガラスからなる光導波路、基板上に配置された光ファイバなど）であり得る。このとき、他方の光デバイスは、前記基板に対し概ね垂直な方向の光を発光あるいは受光する面型光デバイスであり得る。更に、この場合、楕円球曲面ミラーは、

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前記光導波路の端面近くに位置して、エッチング或は転写にて前記基板に形成された凹面ミラーであり得る。

【００１０】また、発光あるいは受光する面型光デバイスが形成されている基板の該光デバイスの部分上に楕円球状の凸部から成る楕円球曲面ミラーが設けられている形態も取り得る。

【００１１】より効率の良い光結合を達成するには、前記楕円球曲面ミラーの楕円球の２つの焦点のうち、一方の焦点の近傍にに第１の光デバイスが配置され、他方の焦点の近傍に第２の光デバイスが配置されているのが良い。この場合、前記楕円球曲面ミラーの楕円球の２つの焦点のうち、一方の焦点の近傍に発光あるいは受光する面型光デバイスが配置され、他方の焦点の近傍に光導波路の端面が配置され得る。

【００１２】同じく、より効率の良い光結合を達成するには、前記楕円球曲面ミラーの曲面には高反射膜が形成されるのが良い。

【００１３】更に、上記目的を達成するための本発明の楕円球曲面の作製方法においては、ほぼ楕円球の一部で構成された楕円球曲面が、（ａ）基板上に所定の角度を有する斜面を形成する工程、（ｂ）該斜面上に長方形状あるいは楕円状の開口部を有するマスクを形成する工程、（ｃ）該開口部を通じて基板を等方的にエッチングする工程、によって形成されることを特徴とする。

【００１４】前記楕円球曲面ミラーを形成する基板を、この作製方法によってエッチングすることで、上記の光結合器を容易に作製できる。

【００１５】また、上記目的を達成するための本発明の楕円球曲面の作製方法においては、ほぼ楕円球の一部で構成された楕円球曲面が、（ａ）導電性部分を少なくとも一部に有するメッキ用基板を用意する工程、（ｂ）該メッキ用基板の導電性部分上に開口部を有するマスクを形成する工程、（ｃ）該メッキ用基板の導電性部分を陰極とした電気メッキにより、前記開口部を通じて開口部およびマスク上にメッキ層を形成する工程、（ｄ）該メッキ層を有するメッキ用基板を金型として、他の基板にメッキ層の形状を転写する工程、によって形成されることを特徴とする。

【００１６】この楕円球曲面の作製方法では、前記メッキ用基板に予め所定の角度を有する斜面を形成し、該斜面上に開口部を有するマスクを形成すれば、適当に傾斜した楕円球曲面が形成できる。

【００１７】この際、前記開口部が長方形状あるいは楕円状であり、前記（ｃ）の工程において、メッキ液を静止させた状態で楕円球状のメッキ層を形成したり、前記開口部は円形状であり、前記（ｃ）の工程において、メッキ液を開口部上で一方向に所定の流速にて流動させて楕円球状のメッキ層を形成したりすることができる。

【００１８】前記楕円球曲面ミラーを形成する基板に、これらの作製方法によって形成された前記メッキ層の形

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状を転写することで、上記の光結合器を容易に作製できる。

【００１９】上述の面型光デバイスが形成されている基板の該光デバイスの部分上に楕円球状の凸部から成る楕円球曲面ミラーが設けられている形態の結合器の作製は、上記の作製方法によって形成された楕円球状の凹部を有する基板を金型として、光デバイスが形成されている基板上に楕円球状の凸部を形成することで行ない得る。

【００２０】更に、上記目的を達成するための本発明の光送受信装置は、上記の光結合器が光導波路の両端部に形成されており、一組の発光素子、受光素子、および光導波路が光学的に結合されていることを特徴とする。

【００２１】更に、上記目的を達成するための本発明の光インターコネクション装置は、上記の光送受信装置を用いて、半導体回路チップ内の光配線、半導体回路チップが複数実装されたチップモジュール同士の光配線、半導体回路チップおよびチップモジュールが実装されたボード内の光配線、或は半導体回路チップおよびチップモジュールが実装されたボード同士の光配線を行なうことを特徴とする。

【００２２】本発明の作用原理を説明する。楕円球には２つの焦点が存在し、その一方の焦点から発せられる任意の方向へのベクトルが楕円球の曲面で反射した場合、必ず他方の焦点を通るベクトルとなることが知られている。すなわち、楕円球の２つの焦点のうち、一方の焦点の近傍に、例えば面発光レーザのような面型光デバイスを配置し、他方の焦点の近傍に、例えば光導波路の端面を配置すれば、面型光デバイスから発せられた発散光は、楕円球の曲面で反射して光導波路に向って集光する光に変換されることになる。こうして、効率よく光の結合を行なうことができる。また、４５°ミラーと集光レンズを用いる場合に比べ、構成がシンプルで各要素のアライメントも容易である。

【００２３】上述した如く、楕円球状の曲面を形成するには、ウエットエッチング等の等方性エッチングを用いて基板上に楕円球状の凹部を形成する方法、電気メッキ法によって基板上に楕円球状の凸部を形成する方法などがあるが、これらの方法は、基板上に同時に多数の楕円球構造を形成できるのでアレイ化が容易である。また、これらの方法で形成された構造を金型として別の基板に該構造の凹凸を反転して転写させてもよい。金型を用いる場合は、金型の再利用が可能であるため生産性が向上する。

【００２４】また、本発明の光結合器を基板上に複数設けた場合、例えば、光導波路の両端に光結合器を形成し、さらに光導波路と光結合するように発光素子、受光素子を配置すれば、一対の光送受信装置が構成できる。さらに、チップ内、チップ間、ボード内、ボード間の光インターコネクションに応用することも可能であり、高

速・並列伝送を実現することができる。

【００２５】

【発明の実施例の形態】以下、図面を参照しつつ本発明の実施の形態を説明する。

【００２６】（第１実施例）図１、図２を用いて本発明の第１の実施例を説明する。図１は本発明による光結合器の第１実施例の断面図、図２はその作製工程を説明する図であり、図２においては、断面図に加えて上面図も合わせて記載してある。

【００２７】図１において、１１はＳｉ基板、１３は楕円球状の凹部、１５はその凹部１３上に設けられたＡｌからなる反射膜、１７は光導波路であり、この光導波路１７は上下のクラッド層１９、２３とコア層２１から成っている。更に、２５は面型光デバイスが形成されているＧａＡｓ基板であり、２７が面発光レーザである。また、２９は基板１１、２５同士を接着する接着剤である。

【００２８】面発光レーザ２７の発光部およびコア層２１の端部（図１中、左端）は、夫々、部分的楕円球状の凹部１３の２つの焦点に来るように配置されている。したがって、面発光レーザ２７から発散して楕円球状の凹部１３に当たった光は、反射膜１５で反射してコア２１の左端に向って集光する光に変換されることになる（図１中、矢印を参照）。こうして、効率よく光を結合させることが可能となる。

【００２９】楕円球状の凹部１３の作製方法について図２を用いて説明する。Ｓｉ基板１１上にエッチングマスク１０１を形成し（図２（ａ））、異方性エッチングにより基板１１の基準面に対して所定の角度を有する斜面１０３を形成する（図２（ｂ））。この時、例えばＳｉ基板１１として（１００）面（上記基準面）を持つ基板を用い、エッチングマスク１０１を＜０１１＞に平行な方向にパターニングしておく。そして、エッチング液として水酸化カリウム水溶液を用いることにより、斜面１０３を（１１１）面とすることができる。この場合、基板面（基準面）と斜面１０３の角度は５４．７°となる。

【００３０】次に、図２（ｃ－１）、図２（ｃ－２）のように、斜面１０３上に、Ａ－Ａ’方向に長手方向を持つ長方形の開口部１０７を斜面１０３の所に設けたエッチングマスク１０５を形成する。

【００３１】次いで、開口部１０７を通して、弗酸、硝酸、酢酸の混合水溶液を用いて等方性エッチングを行ない、楕円球状の凹部１３を形成する（図２（ｄ－１）、図２（ｄ－２））。さらに、エッチングマスク１０５を除去する（図２（ｅ－１）、図２（ｅ－２））。この時、形成された楕円球（半楕円球）の長径は５０μｍ、短径は２５μｍであった。こうして形成された凹部１３は厳密な楕円球とは言えないが、本発明の光結合器として充分な機能を持つ程度には楕円球に近い形状となる。

【００３２】さらに、凹部１３に反射膜１５としてＡｌを蒸着した後に、光導波路１７を形成する（図２（ｆ））。光導波路１７は、高屈折率のポリイミド樹脂からなるコア層２１の回りを、該コア層２１に対して低屈折率のポリイミド樹脂からなるクラッド層１９、２３で覆った構成である。コア層２１の断面形状は４μｍ×４μｍの矩形とした。また、楕円球状の凹部１３の一方の焦点近傍に光導波路１７の端が来るように、光導波路１７の端面をエッチングしてある。この設定は、後の面発光レーザ２７の位置合わせで補償できるので、ここで述べた様に一方の焦点近傍でよい。

【００３３】この光導波路１７の作製は、例えば、クラッド層１９の成膜、コア材料の成膜後のパターニングとエッチングによるコア層２１の形成（パターンを有するマスク形成後のコア層２１の成膜及びリフトオフでもよい）、コア層２１の両横と上へのクラッド層２３の成膜、光導波路１７の左端部のエッチングにより行なわれる。

【００３４】この様に作製した光導波路１７、ミラー１５を含む基板１１上に面発光レーザ２７を図１のように接着する。この接着に先立ち、接着を容易にするためと面発光レーザ２７の発光端を楕円球状の凹部１３の他方の焦点に合わせ易くするために、Ｓｉ基板１１の表面は平坦化処理されている。本実施例では、接着剤２９として紫外線硬化性樹脂を用いている。

【００３５】図１の構成において、面発光レーザ２７の搭載位置を決定するには、例えば、次のようにする。光導波路１７の図示していない他端側に光パワーメータを設けておき、面発光レーザ２７を発光させた状態で基板１１上で少しずつ移動し、パワーメータの出力が最大になったところで接着剤２９を硬化させてレーザ素子２７を固定する。これにより、上記光導波路１７の端面のエッチング誤差を補償できる。

【００３６】また、他の方法としては、予め位置決めが容易なようにアライメントマーカを双方の基板１１、２５に設けておき、両マーカを合わせることによりレーザ素子２７の位置合わせを行なってもよい。

【００３７】以上のように、本実施例では、図１の断面内に限らず、楕円球の２つの焦点を結ぶ軸の周りの全断面内で集光作用があるので、結合効率な高い光結合器が実現できるとともに、面発光レーザと集光レンズと４５°ミラーを使うといった従来の例に比べ、構成がシンプルで、小型化にも優れている。

【００３８】本実施例では、面型光デバイスとして面発光レーザを用いたが、例えば、発光ダイオードであったり、ホトダイオードのような受光デバイスであってもよい。更には、光ファイバなどの他の光導波路端を図１のデバイス２７の発光箇所の所に設置してもよい。

【００３９】また、接着剤として紫外線硬化樹脂を用いたが、熱硬化樹脂であったりしてもよい。基板１１とし

て、配線が施されているＳｉ基板を用いて、導電性接着剤やハンダなどで両基板側の電極パッド同士の接着および電気的接続を行ないつつ基板の接着を行なってもよい。

【００４０】また、開口部１０７は楕円形状であってもよい。光導波路としては、ポリイミド樹脂で構成したが、SiO_2、SiN_x等のガラス材料であってもよい。加えて、光ファイバの様なフレキシブル導波路をその導波路端が楕円球状凹部の一方の焦点に来るように配置してもよい。この時、フレキシブル導波路のアライメントが容易なように基板１１上にＶ溝のようなガイドを設けておいてもよい。

【００４１】また、Ｓｉ基板１１として（１００）面を用いているが、別の面方位の基板を用いることで、異方性エッチングによって現れる（１１１）面の基板の基準面に対する角度を変えることができる。また、平滑な斜面が得られるのであれば、異方性ウエットエッチングに限ったものではなく、ドライエッチングなどで基板をエッチングしてもよい。

【００４２】更に、Ｓｉ基板に限ったものではなく、石英基板やその他のガラス基板などであってもよい。反射膜１５としてはＡｌを用いたが、例えば、Ａｕなどの金属であってもよく、また、Ｓｉ／SiO_2などの誘電体多層膜であってもよい。

【００４３】（第２実施例）図３、図４を用いて本発明の光結合器の別の作製方法を示す。この第２実施例では、電気メッキ法を用いて楕円球状の凸部を形成していることが特徴である。

【００４４】まず、Ｓｉ基板２１１上にエッチングマスク２０１を形成し（図３（ａ））、異方性エッチングにより、基板２１１の基準面に対して所定の角度を有する斜面２０３を形成する（図３（ｂ））。この時、例えば、Ｓｉ基板２１１として（１００）面を持つ基板を用い、エッチングマスク２０１を＜０１１＞に平行な方向にパターニングしておく。そして、エッチング液として水酸化カリウム水溶液を用いることにより、斜面２０３を（１１１）面とすることができる。この場合も、基板面（基準面）と斜面２０３の角度は５４．７°となる。

【００４５】次に、図３（ｃ）のように、電気メッキの際に陰極となるＣｒ／Ａｕからなる電極２０４を全面に成膜する。さらに、図３（ｄ－１）、図３（ｄ－２）に示す様に、斜面２０３上に、Ａ－Ａ’方向に長手方向を持つ長方形の開口部２０７を斜面２０３に設けたメッキ用マスク２０５を形成する。

【００４６】次いで、この電極付き基板をワークとし、電極２０４を陰極として、硝酸ニッケル、塩化ニッケル、ほう酸、光沢剤からなるＮｉメッキ液を用いて、温度５０℃、陰極電流密度５Ａ／dm^2で電気メッキを行なう。この時、Ｎｉは開口部２０７を中心として等方的に成長するため、楕円球状の凸部２０９を形成できる（図３（ｅ－１）、図３（ｅ－２））。形成された楕円球（半楕円球）は長径５０μｍ、短径２５μｍであった。この楕円球状凸部２０９の形成原理と厳密さについては、エッチングが電気メッキに置き換わるのみで、第１実施例で述べた楕円球状凹部の場合の事情と同じである。

【００４７】この楕円球状凸部２０９を有する基板２１１を金型として、楕円球状凹部を形成する。その作製方法を図４で説明する。

【００４８】まず、紫外線硬化樹脂３１２を金型に滴下し、その上に支持基板３１１となる石英基板を載せ、紫外線を照射して樹脂３１２を硬化する（図４（ａ）参照。ここでは上下を逆転して描いてある）。金型を剥離すると、図４（ｂ）のような楕円球状の凹部３１３を有する構造体３１１、３１２ができる。

【００４９】次いで、凹部３１３に反射膜３１５としてＡｌを蒸着する（図４（ｃ））。更に、光導波路３１７を形成する（図４（ｄ））。光導波路３１７は、高屈折率のポリイミド樹脂からなるコア層３２１の回りを、該コア層３２１に対して低屈折率のポリイミド樹脂からなるクラッド層３１９、３２３で覆った構成であり、コア層３２１の断面は４μｍ×４μｍの矩形とした。この作製は、第１実施例のものと同じである。楕円球状の凹部３１３の一方の焦点に光導波路３１７の端が来るように光導波路３１７の左端面をエッチングするのも、第１実施例と同様に行なう。

【００５０】この後、第１の実施例と同様に、作製した光導波路３１７、ミラー３１５を含む基板３１１の平坦化処理を行なった後に、面発光レーザ等の面型光デバイスを接着する。

【００５１】本実施例においても、第１の実施例と同様、結合効率の高い光結合器が実現できる。さらに、図３（ｅ－１）、図３（ｅ－２）の構造体からなる金型は、再利用可能であるため、光結合器の生産性が向上する。

【００５２】本実施例において、Ｎｉからなる楕円球状の凸部２０９を作製したが、メッキ材料は電気メッキが可能であれば何でもよく、例えば、Ａｕ、Ｐｔ、Ｃｒ、Ｃｕ、Ａｇ、Ｚｎ等の単金属、あるいはＣｕ－Ｚｎ、Ｓｎ－Ｃｏ、Ｎｉ－Ｆｅ、Ｚｎ－Ｎｉ等の合金であってもよい。また、支持基板３１１として石英を用いたが、これに限ったものではなく、ガラス基板やＳｉ、ＧａＡｓ、ＩｎＰ等の半導体基板であってもよい。更に、メッキの際の開口部２０７の形状は楕円であってもよい。

【００５３】（第３実施例）図５、図６を用いて本発明の光結合器の更なる別の作製方法を示す。この第３実施例では、第２の実施例とは異なる電気メッキ法を用いて楕円球状の凸部を形成していることが特徴である。

【００５４】まず、Ｓｉ基板４１１上に、電気メッキの際に陰極となるＣｒ／Ａｕからなる電極４０４を全面に

成膜し、ホトレジストからなるメッキ用マスク４０５を全面に塗布し（図５（ａ））、メッキ用マスク４０５に直径５μｍの円形の開口部４０７を設ける（図５（ｂ））。

【００５５】次いで、この電極付き基板をワークとして、電極４０４を陰極として、硝酸ニッケル、塩化ニッケル、ほう酸、光沢剤からなるＮｉメッキ液を用いて電気メッキを行なう。電気メッキの方法を図７で説明する。

【００５６】図７において、５５１は陽極側の電極、５５３はメッキ液である。この時、図７に示す様に、基板４０４、４０５、４１１を浸漬したメッキ液５５３に、スターラー５５５を一方向に回転して一定方向の流動を起こさせることで、開口部４０７上に流速を形成させておくと、上流側の方が下流側より金属イオンの供給が多いため成長速度が速くなる。本実施例では、スターラー５５５の回転速度は５００ｒｐｍとし、基板の開口部４０７を回転中心より１ｃｍ外側の位置に配置した。また、メッキ液５５３の温度を５０℃、陰極電流密度を５Ａ／ｄｍ^{2}とした。

【００５７】その結果、メッキ液５５３の流動方向に沿った断面で見て、図５（ｃ）の状態を経て図５（ｄ）のような右側（上流側）に偏った楕円球状の凸部４０９を形成できた。流動するメッキ液でこの様な楕円球状凸部が形成される理由は、静止メッキ液では半球状凸部が形成されるところ、メッキ液の流動で頂上部が上流側に若干ずれて楕円球状近似体になると考えられる。この時に形成された楕円球は、頂上部で高さ１５μｍであり、基板を上から見て、その輪郭は縦３０μｍ、横４０μｍであった。この断面における楕円の長軸方向は、開口部４０７の中心を通って図５（ｄ）の鎖線で示す様に基板面に対して傾いている。この楕円球状凸部４０９を有する基板を金型として、楕円球状凹部を形成する。

【００５８】その作製方法を図６で説明する。まず、紫外線硬化樹脂５１２を金型に滴下し、支持基板５１１となる石英基板を載せ、紫外線を照射して樹脂５１２を硬化する（（図６（ａ）参照。ここでは上下を逆転して描いてある）。金型を剥離すると、図６（ｂ）のような楕円球状の凹部５１３を有する構造体５１１、５１２ができる。

【００５９】次いで、光導波路を形成する領域をエッチングして除去し（図６（ｃ））、凹部５１３に反射膜５１５としてＡｌを蒸着する（図６（ｄ））。続いて、光導波路５１７を形成する（図６（ｅ））。光導波路５１７は、高屈折率のポリイミド樹脂からなるコア層５２１の回りを、該コア層５２１に対して低屈折率のポリイミド樹脂からなるクラッド層５１９、５２３で覆った構成であり、コア層５２１の断面は４μｍ×４μｍの矩形とした。ここでも、楕円球状の凹部５１３の一方の焦点に光導波路５１７の端が来るように、光導波路５１７の左端面をエッチングしてある。

【００６０】この後、第１の実施例と同様に、作製した光導波路５１７、ミラー５１５を含む基板５１１の平坦化処理を行なった後に、面発光レーザ等の面型光デバイスを接着する。

【００６１】本実施例においても、第１の実施例と同様、結合効率の高い光結合器が実現できる。さらに、図５（ｄ）の構造体からなる金型は、再利用可能であるため、生産性が向上するとともに、第２の実施例に比べ、基板に斜面を形成するためのプロセスが不要となるので作製が簡単になる。

【００６２】本実施例においても、Ｎｉからなる楕円球状の凸部を作製したが、電気メッキが可能であれば何でもよく、例えば、Ａｕ、Ｐｔ、Ｃｒ、Ｃｕ、Ａｇ、Ｚｎ等の単金属、あるいはＣｕ－Ｚｎ、Ｓｎ－Ｃｏ、Ｎｉ－Ｆｅ、Ｚｎ－Ｎｉ等の合金であってもよい。

【００６３】ところで、第１乃至第３の実施例においては、エッチングあるいは電気メッキによって楕円球状の曲面を作製していたが、その他の方法、例えば、一般的なレーザ加工による物理的加工手段を用いても作製され得る。

【００６４】（第４実施例）次に、図８を用いて本発明の光結合器の別の例を示す。この第４実施例の構造は殆ど第１の実施例と同様であり、共通する部分の詳しい説明は省略する。図８において、図１と同一の部分には同じ番号を付けてある。

【００６５】本実施例では、高屈折率のコア層６２１が低屈折率のクラッド層６１９にぐるりと覆われており、コア層６２１の左端部が楕円球状の凹部１３の一方の焦点に位置しており、加えて、楕円球状の凹部１３もクラッド層６１９で埋め込まれている構成を有する。本実施例では、第１の実施例における光導波路１７の形成法に比べ、光導波路６１７の端部が楕円球状の凹部１３の一方の焦点にほぼ来るように最終的にエッチングして露出させるという工程が不要になるので、その分、工程が簡略化できる。

【００６６】（第５実施例）図９を用いて、本発明による第５の実施例を説明する。本実施例では、上記した実施例において作製された楕円球状の凹部を有する基板を金型として、面型光デバイスを形成した基板上に楕円球状の凸部を転写することによって、光結合器を構成している。

【００６７】図９において、７０１はＧａＡｓ基板であり、７０３は基板７０１に形成された面発光レーザである。上記実施例において作製された楕円球状の凹部を有する基板を金型として、紫外線硬化樹脂からなる楕円球状の凸部７１３を基板７０１上に形成する。

【００６８】さらに、凸部７１３の所定領域を覆うようにＡｌからなる反射膜７１５を成膜し、高屈折率のコア層７２１を低屈折率のクラッド層７１９、７２３で囲ん

だ光導波路７１７を形成する。このとき、楕円球状凸部７１３とコア層７２１の界面での反射を抑える為に、楕円球状凸部７１３とコア層７２１は隙間なく密着していることが望ましい。

【００６９】本実施例においても、面発光レーザ７０３からの光は反射膜７１５で反射して光導波路７１７のコア層７２１の端部に向って集光する光に変換されるので、効率よく光結合を行なうことができる。もちろん、面発光レーザのかわりに発光ダイオードや、ホトダイオード等の受光素子や、他の光導波手段の端部を設置してもよい。

【００７０】（第６実施例）本発明によれば、同様の形状の楕円球状の凹部（あるいは凸部）を同一基板上に同時に多数（複数）形成することができるので、光結合器を基板上に複数設けることが可能である。

【００７１】本発明による光結合器を複数使う例として、光送受信装置に応用した例を示す。図１０の第６実施例において、８０１はＳｉなどで構成された支持基板、８０３、８０５は基板８０１に形成された光結合器、８０７は光導波路、８０９はＧａＡｓ基板、８１１は基板８０９に形成された面発光レーザ、８１３はＳｉ基板、８１５は基板８１３に形成されたホトダイオード、８１７は接着剤である。作製方法は、第１乃至第３の実施例で示した通りである。

【００７２】面発光レーザ８１１からの光は光結合器８０３を介して光導波路８０７に結合される。そして、光導波路８０７を導波して、光結合器８０５を介してホトダイオード８１５で受光される。これまで説明したように、本発明による光結合器の結合効率は高効率であるため、面発光レーザ８１１とホトダイオード８１５は効率よく光接続させられる。

【００７３】本実施例では、ＧａＡｓ基板上の面発光レーザ、Ｓｉ基板上のホトダイオードの例を示したが、これに限ったものではなく、用いる光の波長の応じて最適な発光器／受光器の組み合わせを選べばよい。

【００７４】（第７実施例）本発明による光結合器を複数使う場合として、光インターコネクション装置に応用した例を示す。

【００７５】図１１の第７実施例において、９０１は光導波路９０５および光結合器９０３が複数形成された基板であり、９１１ａ、９１１ｂ、９１１ｃ、９１１ｄはＬＳＩチップであり、この中には電子回路、面型発光デバイス、面型受光デバイスなどが一体化されている。動作は、今までの実施例で述べた通りである。本実施例により、発光デバイス、受光デバイス、電子回路、光結合器および光導波路が一体化したコンパクトな光インターコネクション装置を実現できる。

【００７６】本実施例では、チップ間の光配線の例を示したが、チップ内の光配線や、チップおよびチップモジュールが実装されたボード内の光配線や、チップおよびチップモジュールが実装されたボード同士の光配線に適用してもよい。この場合、必要に応じて、光導波路を光ファイバなどのフレキシブルな導波路で構成すればよい。

【００７７】

【発明の効果】以上説明したように、本発明によれば次の様な効果がある。

（１）ほぼ垂直方向の発光あるいは受光を行なう光デバイスと水平方向の導波を行なう光導波路等を効率よく結合でき、構成がシンプルで、小型化、アレイ化が容易な光結合器を提供することができる。

（２）光結合器を効果的に使用可能な光デバイス、光導波路を提供することができる。

（３）光結合器を、容易に、生産性よく作製できる作製手段を提供することができる。

（４）この様な光結合器を用いた並列伝送可能な光送受信装置、光インターコネクション装置等を提供することができる。

【図面の簡単な説明】

【図１】本発明による光結合器の第１の実施例を示す断面図。

【図２】図１の第１の実施例の作製工程を説明する図。

【図３】本発明による光結合器の第２の実施例における楕円球状凹部を作製する為の金型の作製工程を示す図。

【図４】図４の金型を用いて第２の実施例を作製する作製工程を示す図。

【図５】本発明による光結合器の第３の実施例における楕円球状凹部を作製する為の金型の作製工程を示す図。

【図６】図５の金型を用いて第３の実施例を作製する作製工程を示す図。

【図７】図５の金型の作製工程で用いられる電気メッキ槽の形態を示す図。

【図８】本発明による光結合器の第４の実施例を示す断面図。

【図９】本発明による光結合器の第５の実施例を示す断面図。

【図１０】本発明による光送受信装置である第６の実施例を示す断面図。

【図１１】本発明による光インターコネクション装置である第７の実施例を示す一部分解した斜視図。

【符号の説明】

１１、２５、２１１、３１１、４１１、５１１、７０１、８０１、８０９、８１３、９０１　基板

１３、３１３、５１３　楕円球状の凹部

１５、３１５、５１５、７１５　反射膜

１７、３１７、５１７、６１７、７１７、８０７、９０５　光導波路

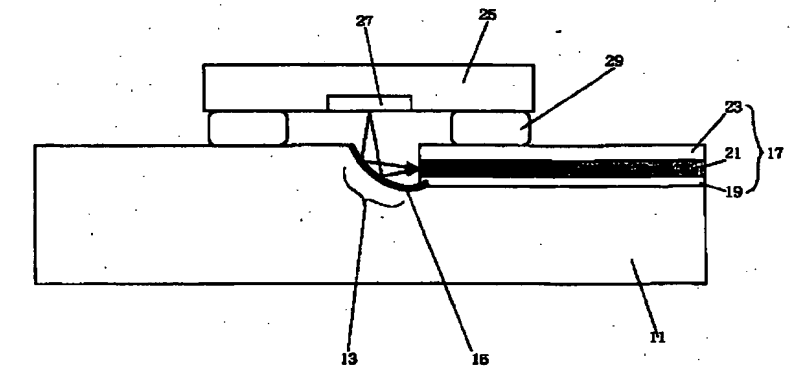
１９、２３、３１９、３２３、５１９、５２３、６１９、７１９、７２３クラッド層

２１、３２１、５２１、６２１、７２１　コア層

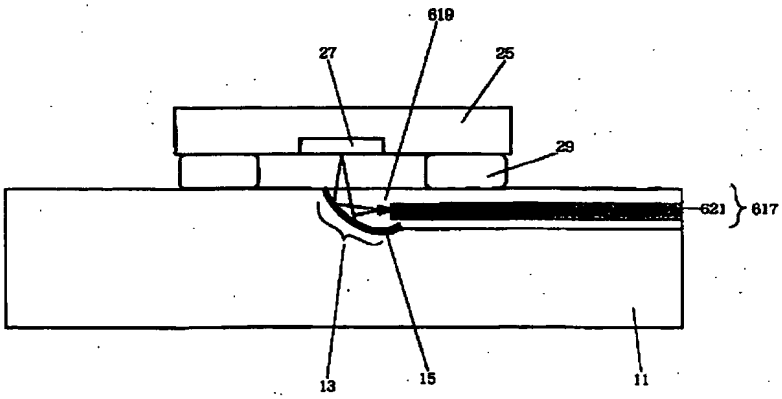
２７、７０３、８１１　面発光レーザ
２９、８１７　接着剤
１０１、１０５、２０１　エッチングマスク
１０３、２０３　斜面
１０７、２０７、４０７　開口部
２０４、４０４、５５１　電極
２０５、４０５　メッキ用マスク
２０９、４０９　金型の楕円球状の凸部
３１２、５１２　紫外線硬化樹脂

５５１　陽電極
５５３　メッキ液
５５５　スターラー
７１３　光結合器の楕円球状の凸部
８０３、８０５、９０３　光結合器
８１５　ホトダイオード
９１１ａ、９１１ｂ、９１１ｃ、９１１ｄ　ＬＳＩチップ

【図１】



【図８】



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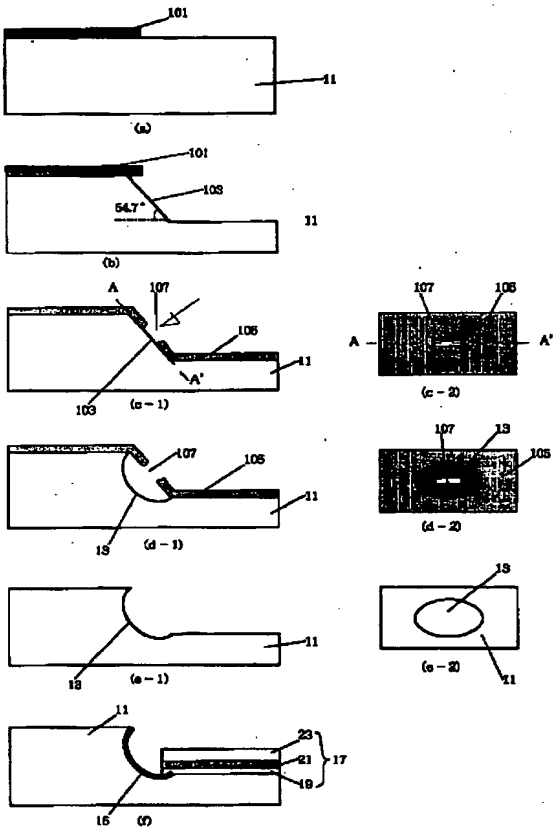
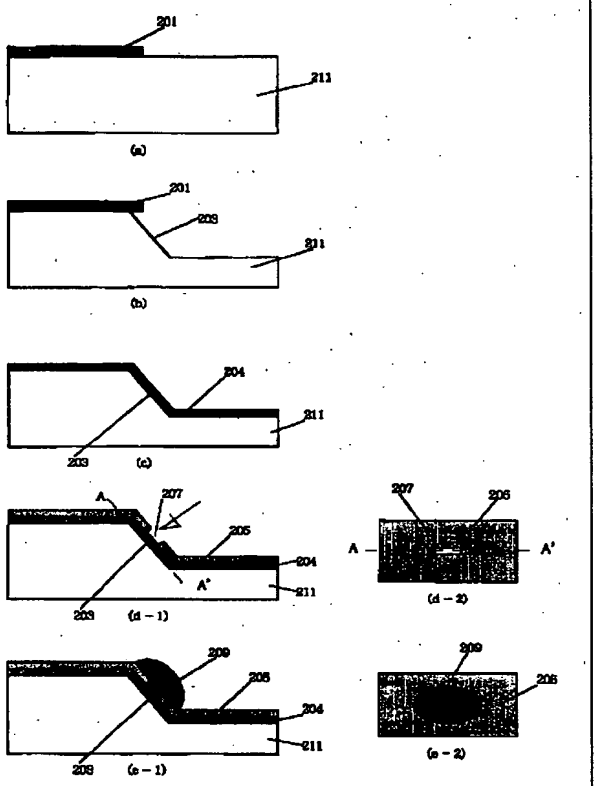
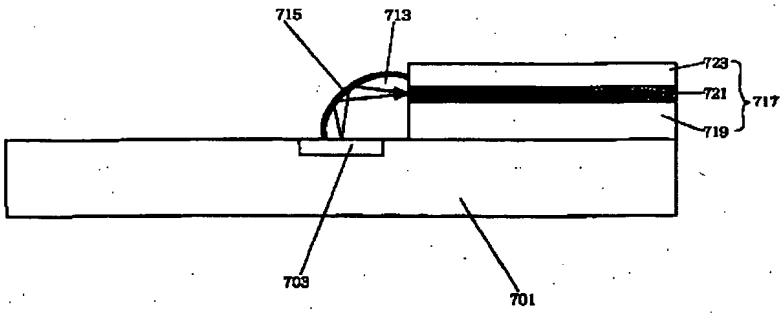

101
11
(a)
101
103
54.7°
11
(b)
A
107
105
A'
11
103
(c－1)
107
105
A
A'
(c－2)
107
105
11
13
(d－1)
107
105
13
(d－2)
11
13
(e－1)
13
11
(e－2)
11
23
21
19
17
15
(f)

【図３】


201
211
(a)
201
203
211
(b)
204
203
211
(c)
A
207
205
204
A'
211
203
(d－1)
207
206
A
A'
(d－2)
209
205
204
211
203
(e－1)
209
206
(e－2)

【図９】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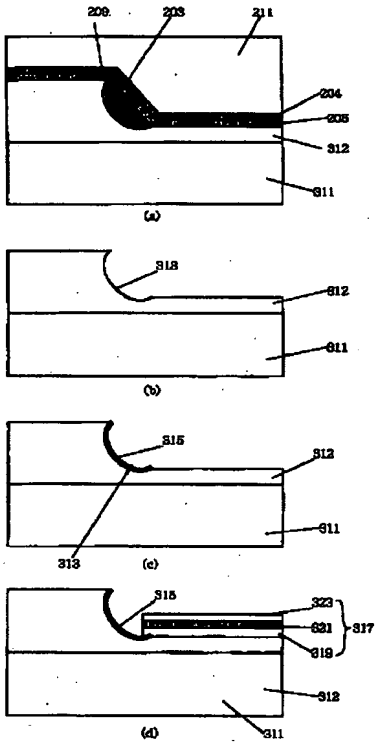
713
723
721
719
717
703
701

【図４】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205
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(b)
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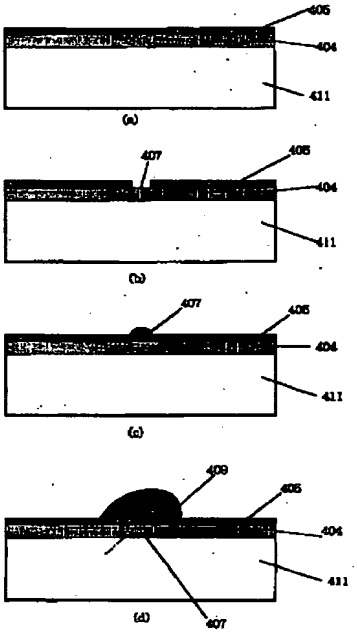
313
(c)
315
323
321
317
319
312
311
(d)

【図５】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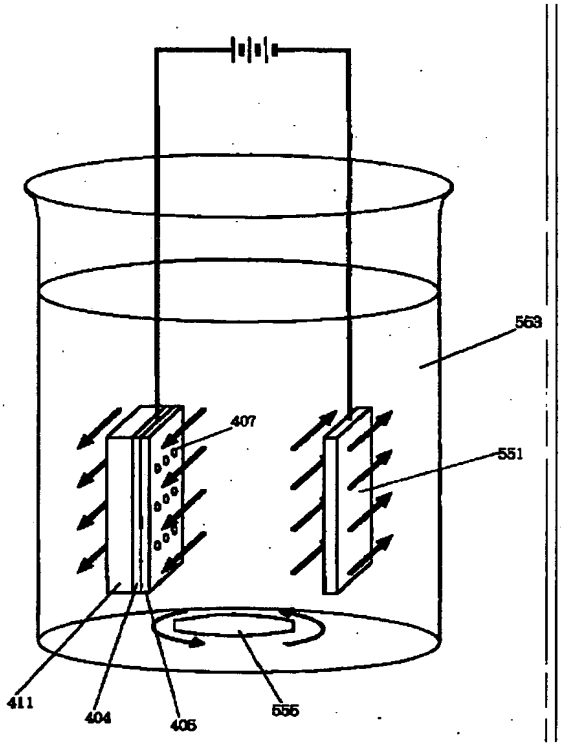
404
411
(a)
407
405
404
411
(b)
407
405
404
411
(c)
409
405
404
411
407
(d)

【図７】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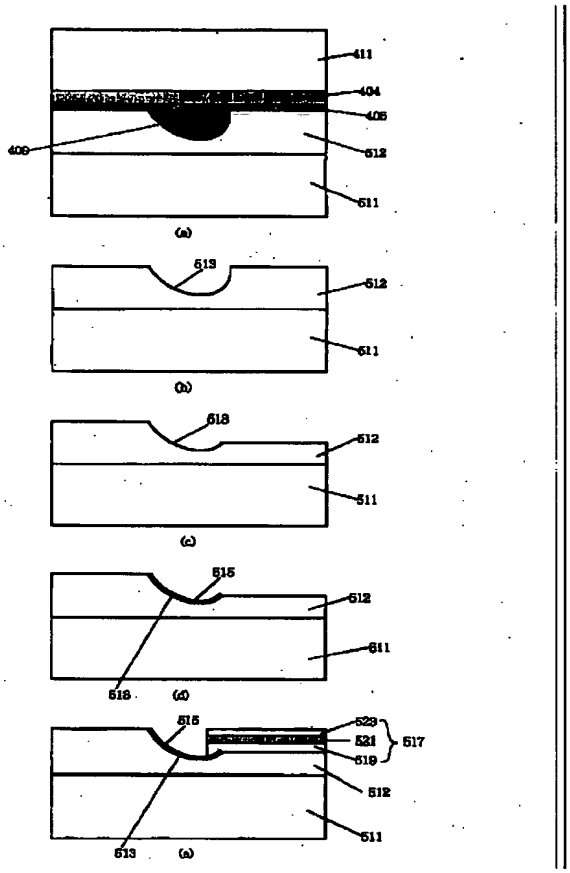
【図６】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512
511
(a)
513
512
511
(b)
513
512
511
(c)
515
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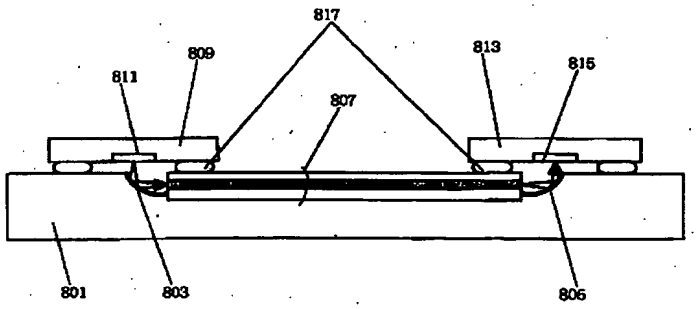
511
513
(d)
515
523
521
519
517
512
511
513
(e)

【図１０】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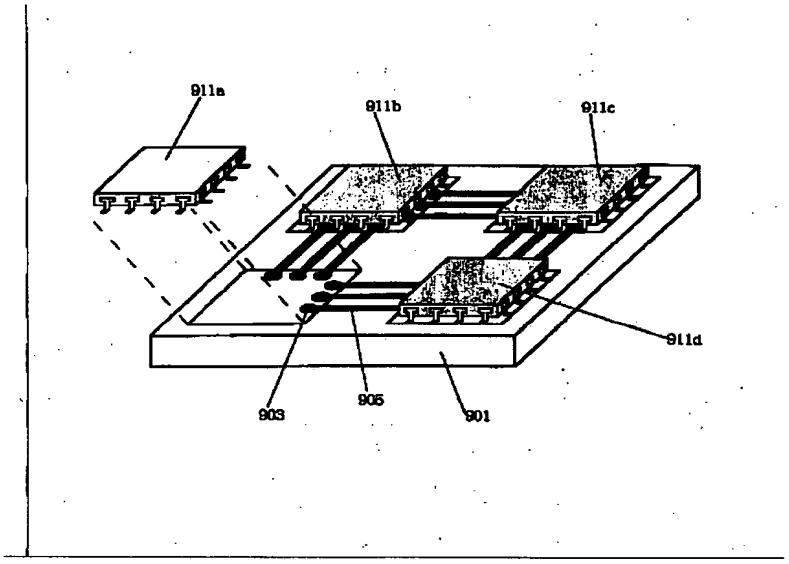
805

【図１１】



フロントページの続き

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JA14 LA01